EFFECTS OF CLOVES, ASHANTI PEPPER AND NEGRO PEPPER AT THREE VARIED LEVELS ON THE QUALITY OF STORED BEEF GRILLED STEAK (*SUYA*) IN ZARIA

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN ANIMAL SCIENCE. DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE AHMADU BELLO UNIVERSITY, ZARIA.

APRIL, 2021

DECLARATION

I declare that this dissertation titled "**EFFECTS OF CLOVES, ASHANTI PEPPER AND NEGRO PEPPER AT THREE VARIED LEVELS ON THE QUALITY OF STORED BEEF GRILLED STEAK (*SUYA*) IN ZARIA**" has been written by me in the Department of Animal Science, Ahmadu Bello University, Zaria, under the supervision of Dr. O.S. Oyadeyi and Prof. T.S. Olugbemi. The information derived from the literature has been duly acknowledged in the text and the list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

Eunice E. MOSES ______________ ______________

Signature Date

CERTIFICATION

This dissertation titled **"EFFECTS OF CLOVES, ASHANTI PEPPER AND NEGRO PEPPER AT THREE VARIED LEVELS ON THE QUALITY OF STORED BEEF GRILLED STEAK (*SUYA*) IN ZARIA"** writtenby **Eunice Enimenoabasi MOSES** meets the regulations governing the award of the degree of Master of Science in the Department of Animal Science of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

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ABSTRACT

A study was carried out to evaluate the effects of ground seeds of cloves, ashanti pepper and negro pepper at three varied levels on the quality of stored beef grilled steak (*Suya*) in Zaria. Fifteen kilogram (15kg) of raw beef was purchased from Zango abbatoir, in Samaru Zaria, Kaduna State. After which it was further processed by cutting into thin sheets of about 7.59-8.79mm in thickness and then staked on skewing sticks before being coated with the spice mix. The experimental design was a 1+3 x 3 factorial arrangement in a Completely Randomized Design (CRD). Treatments consisted of a control (which had none of the spices of interest), Suya Containing Cloves (SCC), Suya Containing Ashanti pepper (SCA) and Suya Containing Negro pepper (SCN) at three inclusion levels (2, 3 and 4%). Treatments were stored at ambient room temperature and sampled on days one, four and seven for physico-chemical, sensory and microbial qualities. Physico-chemical evaluation on day one showed significant (P<0.05) differences across the parameters, with moisture content (MC) ranging between 66.27%(control) to 68.05%(SCA), ash ranged between 1.50% (SCA and control) to 1.91% (SCN), ether extract (E.E) was 5.77% (SCA) to 8.23% (control) and crude protein (C.P) was 20.23% (SCN) to 22.43% (control). Inclusion levels had significant (P<0.05) impact on M.C, ash, E.E, NFE and pH except C.P and TBA. On day four, values across all the parameters were significant having values ranging between 61.59% (control) to 63.71% (SCC) for M.C, ash was 1.64% (SCA) to 2.07% (control), E.E values ranged from 6.19% (SCC) to 7.39% (control) and C.P ranged from 20.19% (SCN) to 22.07% (control). Levels of inclusion had significant effect on all of the parameters except C.P. On day seven sampling period, values across all the parameters were significant (P<0.05) with M.C ranging between 53.06% (control) to 59.75% (SCC), ash ranged from 1.65% (SCA) to 2.44% (control), E.E was 6.31(SCC) to 7.63% (SCA) and C.P was 19.84% (SCA) to 22.36% (control). Levels of inclusion also showed significant (P<0.05) differences across all the physico-chemical parameters. Sensory evaluation of the treatments on day one showed no significant (P>0.05) differences in colour and tenderness, but was significantly (P<0.05) different in flavor with value ranges of 5.94 (SCC) to 6.92 (SCA), while juiciness ranged from 6.26 (SCC) to 6.86 (SCA) and overall acceptability range was 6.44 (SCC) to 7.29 (SCA). Inclusion levels showed no significant (P>0.05) differences. On day four, treatment and varied inclusion levels had no significant (P>0.05) effect across the sensory parameters. On day seven, there were also no significant (P<0.05) differences acorss treatments, but at varied inclusion levels, only color was significant (P<0.05) with 3% inclusion level having the higher value of 6.34. Microbial studies on days one and four showed no detectable fungal counts, while total viable bacteria counts (TVBC) ranged between 1.70log (SCN)) to 3.11log (SCC) on day one and 3.82log (SCA) to 6.18log (control) on day four. Coliform counts values ranged between 2.09log (SCN) to 2.45log (SCC) on day one and 3.21log (SCA) to 3.90log (control) on day four. However on day seven, only SCA was still within the safe limits for human consumption having acceptable TVBC values (5.71log) and coliform counts (3.61log) with zero fungal counts. In conclusion, based on overall performance in sensory and microbial qualities over the seven day period of sampling, SCA is most recommended.

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ABBREVIATIONS

AOAC = Association of Official Analytical Chemists

CP = Crude Protein

EE = Ether Extract

ICMSF = International Commission on Microbiological Specifications for Foods

IMM = Intermediate Moisture Meat

MC = Moisture content

NFE= Nitrogen free extract

pH= Potential Hydrogen

TBA= Thiobarbituric Acid

TMC = Total Mould count

TVBC= Total Viable Bacteria Count

TYC = Total Yeast Count

WHO= World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

Intermediate moisture (IM) meat products are processed almost everywhere in the world and each product has its own characteristics (Chang *et al.,* 1996). One of such IM meat products is grilled steak. Grilled steak commonly called "*Suya*" is a common local delicacy found in most part of Nigeria, but most prevalent in the Northern part of the country (Agencie France Press, 2012). *Suya* is also found in Cameroon, Ghana, Niger, and some parts of Sudan (Eke *et al.,* 2013). It is prepared mostly from beef, and sometimes from mutton, goat meat and even chicken. Some of the common spices and ingredients often used are salt, pepper, curry, thyme, groundnut oil etc; Ingredients may vary according to personal and regional preferences as there is no standard recipe to produce the complex mixture of spices and additives which makes up the s*uya*spice mix and the garnish (*yaji)* mix served with it. However, meat is the major component of*suya*.

Meat which is the main source of animal protein for human beings is highly vulnerable to spoilage due to its high moisture content and rich nutrient makeup, thus it provides favorable environment for the growth of microorganisms which leads to meat deterioration and negatively affects meat quality. This has necessitated the processing of fresh meat into meat products. The original aim of meat being processed was preservation, however, since the various procedures involved in the processing causes so many changes in texture and aroma, it has become a means of adding variety to the diet and it also helps to improve customer satisfaction and the maintenance of the consistency of meat products which are a major concern and challenge for the meat industry world-wide (Behrends *et al.,* 2005).

Food security remains a complex issue, where animal proteins such as meats, meat products, fish and fish products are generally regarded as a high risk commodity to infection and toxication (Yousef *et al.*, 2008). These food borne infections and the consequent illnesses are some of the major international challenges that lead to high mortality and economic loss (Adak *et al.*, 2005). This growing concern about food safety has recently led to the development of natural antimicrobials to control food borne and spoilage microorganisms (Pundir and Sharma, 2010) as exploitation of other avenues of meat preservation has been suggested but these methods rarely achieve their aim due to their sophistication, which requires constant and reliable power supply that is almost absent in most developing countries (Abubakar, *et al.*, 2011) of which Nigeria is among.

One of such natural antimicrobials are spices which human beings from time, have relied immensely on as key ingredients for preparing and processing food all over the world. Spices are used in the meat industry for curing and preservation of meat (Ogunsola, 2006) as they possess a series of chemical constituents in their nature which helps them act as antimicrobial agents (Prince and Prabakaran, 2011). In Nigeria and most parts of West Africa, some of this spices are used as condiments for cooking delicacies because of their unique *aroma*tic taste and attractive *aroma*and some of this spices are the Negro pepper (*Xylopia aethiopica*), Clove (*Eugenia aromatic*) and Ashanti pepper (*Piper guineense*) which are the three spices of interest in this study.

In Nigeria Ashanti pepper goes by some names such as*'Masoro'*(Hausa)*'Uziza'* (Igbo)*, 'Iyere'* (Yoruba), etc. The spice is obtained from its dried fruit commonly known as *Uziza*, West African pepper, *Ashanti* pepper, Benin pepper, Guinea *cubeb*. Negro pepper is commonly known as '*Kimba'* (Hausa) *'Uda'* (Igbo), '*Erunje'*(Yoruba),*selim* pepper, Sénégal pepper, *kimba* pepper, Ethiopian pepper. Clove is commonly known as'*kanumfari'* (Hausa), kanafuru (Yoruba), kloovu/ ncharra (Igbo) etc. Much has been documented on the nutritional, sensory and antimicrobial properties of these plants (Ezekwesili *et al.*, 2010; Tajkarimi *et al.*,2010; Anyanwu and Nwosu, 2014).

It is thus the assumption of this author that these spices will not only improve the sensory and nutritional properties of the *Suya*, but will also reduce the potential of deterioration and contamination of the *Suya*thus improving the overall quality of the stored product. Therefore, this study sets out to find out the effects of three selected spices (clove, ashanti pepper and negro pepper) at three varied inclusion levels (2%, 3% and 4%) quality of *Suya* when sampled at three different days (1, 4 and 7 days) in Zaria, Kaduna state.

1.1. Statement of Problem

Beef is one of the contributors to the national economy and food security of many countries of the world and here in Nigeria, meat supply is currently undergoing tremendous transformation (Balarabe, 2016) such as the processing of fresh meat into various meat products that have found a niche in almost every households like the *suya*, *tukunya, dambunnama* etc.

Suya is a popular meat product that is greatly relished by consumers however sales-points hardly exhaust their sales and leftovers are often carried over to the second day or beyond. To this extent, rancidity often sets in, leading to the spoilage of this product. It is recognized that spices and herbs fulfill more than one function in foods to which they are added. The study of plant extracts as food preservatives is especially of value here in Nigeria where the incessant power outage has made cold storage non-realistic.

Spices are natural foodstuffs, and they appeal greatly to consumers who tend to question the safety of synthetic food additives; with the recent outbreak of health cases related to processed animal products, such as the Polony outbreak in South Africa, there is need for processed meat to be given much attention and further research conducted with the aim to providing solutions that will hinder a reoccurrence or lessen such in our modern processed food conscious society.

Therefore, evaluation of simple, appropriate and affordable means sustainable and applicable to local environment is pertinent especially in relation to the ever increasing demand for *suya*and various other intermediate moisture meat by consumers locally and worldwide.

1.2. Justification of the study

There is need for research into alternative means of preserving a highly demanded meat product such as s*uya* in a way that is reliable, affordable and sustainable in an environment with incessant power outage such as Nigeria, to avoid detrimental effects of a deteriorated meat product to the health of its consumers.

There is paucity of information on physico-chemical composition, organoleptic properties and microbiological analysis of s*uya* processed using cloves (*Eugenia aromatic*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethiopica*)and their effects at varied inclusion levels in literature.

This study focus was on assessing the effects of the three selected spices and their varied inclusion levels on the quality of stored*Suya*with a view of establishing natural preservation methods.

1.3. Objectives

The purpose of this study was to find out the overall quality of stored *suya*when processed using three spices (cloves, ashanti pepper and negro pepper) at three varied inclusion levels. However the specific objectives was:

- To estimate the effect of varied levels of dried ground seeds of cloves (*Eugenia aromatic*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethiopica*)in *suya*spice mix on the physico-chemical properties of stored suya.
- To estimate the effect of varied levels of dried ground seeds of cloves (*Eugenia aromatic*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethiopica*)in *suya* spice mix on the organoleptic properties of stored *suya*
- To estimate the effect of varied levels of dried ground seeds of cloves (*Eugenia aromatic*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethiopica*)in *suya* spice mix on the microbiological properties of stored *suya.*

1.4. Hypotheses

This research therefore, was designed to evaluate the following null hypothesis (HO)

> Ho: There is no significant difference in the physico-chemical, organoleptic and microbiological properties of stored *Suya*when prepared with cloves (*Eugenia aromatic*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethiopica*)*aromatic*at varied inclusion levels.

The alternate hypotheses states otherwise

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature that are related to the study including physical and chemical properties of meat, common beef processing methods and their effects on physiochemical properties of meat, various types of processed meat products, fresh processed meat and their physiochemical properties, organoleptic properties of meat products, effects of processing methods on organoleptic properties of meat, a review of various microbiological effects on processed meat products and the effects of spices on meat quality and shelf-life with emphasis on the three spices selected for this study which are clove (*Eugenia aromatica*), Ashanti pepper (*Piper guineense*) and Negro pepper (*Xylopia aethiopica*)The chapter further discusses their uses and various works of research that had been carried out on them which will be critical to the appraisal of this study.

2.1 Physical and Chemical Properties of Meat

Meat is the indispensable component of the highest quality of the right and well-balanced human diet (Biesalski, 2005). Meat is composed of water, protein, fat and other water-soluble organic material as shown in Table 2.1.

2.2 Some Common Beef Processing Methods and their Effects on Physiochemical Properties of Meat

Meat as a result of this rich makeup, is usually prone to high microbial activities which results in the deterioration of its quality. Thus it is usually processed as soon as slaughtering takes place not just to lessen microbial activities but also to improve overall sensory qualities and palatability for human consumption. Some of the common processing methods are discussed below.

Table 2.1: Nutritive composition of beef

Substance	**Composition**	**Proportion%**
Water	Hydrogen, oxygen	73
Protein	Amino acids	22
Fat	Phospholipids, Cholesterol and Fat soluble vitamins	3.9
Other soluble organics	Vitamins, Carbohydrates	1.1

Source: Rendle and Keeley (1998), Gandi (2014)

2.2.1 Smoking

McGee (2004) reported smoking to be the process of flavoring, cooking or preserving food by exposing it to smoke that is as a result of burning or smoldering plant materials most often wood. Meats and fish are the most commonly smoked foods. Ogunbanwo *et al.* (2004) also reported that smoking has a preservative effect on the *suya* meat.

Myrvold (2011) observed that a type of smoking called hot smoking occurs within the range of 52 to 80 °C and that within this temperature range, meat is fully cooked, moist and flavorful. If the smoker is allowed to get hotter than 85°C, the meat will shrink excessively. Smoking at high temperatures also reduces yield, as both moisture and fat are cooked away. Gandi (2014) in his investigation on the quality of beef when smoked with different plant materials found out that dry matter content of the *suya* ranged from 50.37 to 64.04%, while the crude protein ranged between 40.93 - 43.87 %. He reported values for crude fiber to range from 5.89 %, to 7.98 % and that of ash was 2.27 to 5.03. He further reported nitrogen extract values of 40.47 to 45.7 and moisture content range of between 31.79 – 40.35%.

2.2.2 Roasting

This is a method of processing in which food is uncovered in hot air at a temperature that usually ranges between 149-177^{o}C. With roasting, direct heat is applied to the food. The heat seals the outside part of the food and the juice inside the food cooks the food. Roasting is mainly used when cooking fleshy food like fish, meat or chicken. When heat is applied to the outer covering of the food, it seals it up thereby trapping all the juices inside the food. Direct heating, heats up the juices inside the food, which then cooks the food. Again there is very little nutrient lost and the flavour is not spoilt. During preparation, food is frequently rotated over the spit so that there will be heating of all parts of the food (Kassim, 2013).

Olusola *et al.* (2012) in their work on *Kilishi*; a type of roasted dried meat product, made from different meat types, reported moisture content of between 5.33- 10% and protein range of between 55.47-69.02%, while fat ranged between 6.88-14.24, and crude fibre was between 2.96-4.42%. Ash and carbohydrate ranges were reportedly 6.96-10.31% and 3.23-12.06% respectively. Idowu *et al.* (2010), reported 9.75% for moisture, 18.10% for fat, 7.10% for ash, 57.02% for protein and 8.05% for carbohydrate. Ogunsola and Omojola (2008) in their own report cited values ranging from 9.92 – 10% for moisture, 59.41-60.33% for protein, 13.33- 14.24% for fat and 6.96-8.78% for ash.

2.2.3 Broiling

This processing is achieved by direct application of heat. In broiling, the food uses a heat source located above the food rather than below. The meat is usually placed on a rack in a shallow broiler pan and the surface of the food lies 8-13 cm (3-5 inches) under the flame in a gas range broilers or below the broiler heating unit in an electronic oven to prevent the air in the oven from becoming too hot (Kassim, 2013).

2.2.4 Frying

Frying is a food processing method used to prepare both homemade and industrial products, which is widespread due to the sensory and organoleptic characteristics that make fried food more attractive to consumers (Simeon *et al.*, 2012). It is a very convenient method of cooking as it is fast and requires little food preparation (Fillion and Henry, 1998). Another reason for its great popularity is that frying generates very palatable foods due to the fat content, the crisp texture and rich flavours. It is mainly a dehydration process and it is an extremely complex process involving many factors some of which are dependent on the process itself and others on the food and the type of fat used (Fillion and Henry, 1998).

Kassim (2013) worked on meat floss and reported moisture contents of between 17.69% and 19.59%, with protein contents range of between 39.75% and 46.73%. The result also showed ash contents of between 1.79% and 3.11%, while ether extract content was from 2.30% to 3.95%. This was slightly different from that reported by Huda *et al.* (2012), who had values ranging from 8.60-13.56% for moisture, 3.20-31.14% for fat, 19.86 -30.15% for protein and 3.17-5.16% for ash. Abubakar *et al.* (2011) in their own work on meat floss, however reported values like 47.1-58% for protein, 24.9-26.9% for ether extracts and 6.2-7.1% for ash.

2.2.5 Grilling

This processing method is much similar to broiling except that here, the food lies directly over the heat source. Grilling cooks food with radiant heat from a source located below it. Some of the juices are reduced directly on the food while the rest drip away. Grilled foods have a smoky, slightly charred flavor resulting from the flaring of the juices and fats that are rendered as the food cooks, as well as from direct contact with the rods of the grill rack. Grilling is often presented as a healthy alternative to cooking with oils, although the fat and juices lost by grilling can contribute to drier food (Beckett, 2012). Different types of grilled beef products available in Nigeria are *suya*, *Tukunya* and *Balangu*, the most popular however is the *suya*.

Adeyeye (2016) who worked on different methods of grilling *suya*, reported that mean moisture contents ranged from 36.80-39.65% with protein contents between 33.42- 37.58%. He further reported that the mean fat contents were between 20.90- 26.10%, with their crude fiber contents being 1.20- 1.36, while the mean ash contents ranged from 2.31-2.86%. The results of rancidity indices revealed thiobarbituric acid values of the samples were between 0.96- 1.90meq peroxide/kg.

2.3 Processed Meat Products

Processed meat is any meat which has been modified in order to either improve its taste or to extend its shelf life. Methods of meat processing include salting, curing, fermentation, and smoking. Meat products can be broadly grouped into six based on the processing technologies used, considering the treatment of raw materials and individual steps (FAO, 2010).

2.3.1 Cured Meat Cuts

Products belonging to this group are made of entire pieces of meat and can be subdivided into two groups: cured-raw meats and cured-cooked meats. The curing for both groups is similar in principle, with the meat pieces treated with small amounts of nitrite, either as dry salt or as salt solution in water (Kassim, 2013).

- **Cured-raw meats:** This does not undergo any heat treatment during manufacture. They only undergo a processing period which comprises of curing, fermentation and ripening in controlled climatized conditions that make the products palatable. The products are consumed raw/uncooked e.g. cured-raw ham

- **Cured-cooked meats**: After the curing process of the raw meat, it then undergoes heat treatment to achieve the desired palatability. Entire pieces of meat and reconstituted products (Kassim, 2013).

2.3.2 Raw-Cooked Meat Products

These groups are a very specific group as their processing technology is different from all the other processed meat products. The utilization of comminuting equipment such as grinders and bowl cutters is essential in their manufacture, in specific cases also emulsion mills. Meat, fat and non-meat ingredients which are the components of the product are processed raw/uncooked by comminuting and mixing. After this, the resulting viscous mix or batter is submitted to heat treatment or cooking or portioned in sausages. This heat treatment is done in order to obtain a firm-elastic texture typical for ready-to-eat raw-cooked products and to achieve palatability and a certain degree of bacterial stability through inducing protein coagulation. Examples of this product are frankfurters, mortadella, meat loaf etc. (Kassim, 2013).

2.3.3 Pre-Cooked Meat Products

These group of meat products are distinguished from other types of processed meat products by precooking the raw materials prior to grinding or chopping, and also by utilizing the greatest variety of meat, animal by-products and non-meat ingredients which contains mixes of lower-grade muscle trimmings, fatty tissues, head meat, animal feet, animal skin, blood, liver and other edible slaughter by-products which are generally of good nutritive value. Two heat treatment procedures are involved in the manufacturing processes of this type of product. The first heat treatment is the precooking of raw meat materials at temperatures below 100^0C, usually in the range of 80^0C and the second heat treatment which is carried out at either pasteurization temperatures of about 80^0C or sterilization temperatures which is above 100^0C, is the cooking of the finished product mix at the end of the processing stage. The processing to precooked-cooked products results in attractive and palatable varieties of animal food items Examples of this meat product includes blood sausage, liver pate and corned beef in cans (FAO, 2010).

2.3.4 Raw-Fermented Sausages

The main characteristics of products in this group are properties which are a result of fermentation processes and they are tangy flavor, chewy texture (in most cases) and intense red curing color. These properties are generated through physical and chemical conditions created in raw meat mixes that are filled into casings. Uncooked meat products which are the typical raw- fermented sausages consist of coarse mixtures of lean meats and fatty tissues combined with salts, nitrite (curing agent), sugars and spices as non-meat ingredients. In order to build-up its typical flavor and texture in the final products, ripening phases combined with moisture reduction are added to fermentation. However utilization of water-vapour permeable casings are necessary for moisture reduction. Products in this group (salami, naem and some traditional Asian products) are not subjected to any heat treatment during processing and are in most cases distributed and consumed raw (Kassim, 2013).

2.3.5 Dried Meat Products

These products are derived through simple dehydration or drying of lean meat in a natural condition or in an artificially created environment. Their processing is based on the fact that dehydrated meat, from which a substantial part of the natural tissue fluid was evaporated, will not easily get spoilt. Pieces of lean meat without adherent fat are cut into specific uniform shape that permits the gradual and equal drying of whole batches of meat. Dried meat is not comparable to fresh meat in terms of shape and sensory and processing properties, but has significantly longer shelf life. Examples are biltong from Southern Africa, meat floss from Africa, East and South-East Asia, kundi in Nigeria (Omojola *et al.*, 2004).

2.3.6 Fresh Processed Meat Products

The main characteristics of this group is that all meat and non-meat ingredients are added fresh (raw or uncooked), this ingredients are either refrigerated or non-refrigerated. The products in this group are burgers, patties, kebab, sausages, etc. This product comprises of meat mixes composed of finely comminuted, minced or sliced meat, with varying quantities of animal fat adhering to the meat or added separately. Although curing is not practiced, flavouring however is done by adding common salt and spices. Frying, cooking and other heat treatments are applied to make the products palatable and only immediately when ready for consumption (FAO 2010). This fresh meat could be processed by mixing with salt and spices and filled into casings e.g. sausages; or simply mincing, blending, mixing with salt and spices and then pan fry e.g. patties, or simply marinating, staking on skewers, and then grilled e.g. *suya*(Kassim 2013). Some of the fresh processed meat products we have in Nigeria are the *Dambun-Nama, Balangu,Tukunya, Kilishi and Suya.*

2.4 Fresh processed meat and their physiochemical properties

2.4.1 Meat floss (*Dambun-nama*)

Meat floss/shredded meat is a dehydrated meat product and is one of the traditional meat-based product popular among Malaysians and the Asian community (Huda *et al*., 2012) while in Nigeria it is a popular traditional meat product among the Northerners that has been produced for years and popularly known as *Danbunama* (Ogunsola and Omojola, 2008). Kalla *et al.* (2005) stated that it is prepared from fresh meat of good grade which is cut into pieces of approximately 4cm by 2.5cm dimensions. This is then washed with clean water and mixed with spices and other ingredients after which is then boiled for about ninety minutes. After boiling, the water is sieved away and the meat is then pounded into shreds using a mortar and pestle thereafter it is shallow fried using vegetable oil to obtain *Dambun-nama* which is usually brownish in color (Katzer and Gernot, 2015). *Danbun-nama* is the Hausa name for meat floss.

Ockerman and Li (1999) described that moisture content of pork floss they worked on ranged from 0.23 - 3.47%. Huda *et al.* (2012) revealed that the moisture content of meat floss samples they worked on were within the range of 8.60-13.56% while lower moisture content (6.50- 7.37%) was reported by Ogunsola and Omojola (2008). it was reported that the moisture content of shredded meat product should be lower than 7% (Fachruddin, 1997). Fat content between 3.20-31.14 % of meat floss samples were reported by Huda *et al.* (2012), but Ockerman and Li (1999) reported that the addition of 2% and 12% lard will produce meat floss with a fat content of 16.89 and 31.33%, respectively. Higher fat contents (35.57-40.85%) were reported by Ogunsola and Omojola (2008) however Fachruddin (1997), stated that the standard fat content for shredded meat product should be lower than 30%.

Huda *et al.* (2012) reported a protein content of meat floss samples to fall within the range of 19.86-30.15% while Ogunsola and Omojola (2008) conveyed a higher protein content of 38.92 to 41.21%. Similar protein content of 34.09-42.90% was also reported for pork floss by Ockerman and Li (1999) while Fachruddin (1997) concluded in his report that the protein of shredded meat product should be more than 15%. Ash contents within the range of 3.17-5.16% was reported by Huda *et al.* (2012) while in Indonesia it was reported that ash content of shredded meat product should be below 7% (Fachruddin, 1997). However, the study of Abubakar *et al.* (2011) revealed that meat floss from non-ruminant such as rabbit contain 59.2% protein, 24.3% ether extract and 5.3 to 7.4% ash content.

2.4.2 *Balangu*

Moshood *et al.* (2012) described *Balangu* to be a type of roasted meat product which involves using boneless flesh, offals and viscera of mutton or beef. The collected boneless raw meat is washed with clean water cut and sliced into a thick sheet of average thickness of 0.9cm-1.5cm then further wide-spread on a clean table. The sliced meat uniformly dusted with little salt and maggi spices is then placed on an iron net skewer and roasted over a smokeless fire for about 40-60 minutes with regular turning and sprinkling of peanut oil to increase the tenderness while smoking and to make the meat products looks very attractive to customers. The distance of the stick to the fire is normally 35cm-40cm and at temperature of approximately 92^0C, but variations occurs between latter or former depending on certain factors like quantity and time factor.

2.4.3 *Tukunya*

Zahraddeen *et al.* (2006) reported *Tukunya* to be a type of intermediate moisture meat whose preparation is much like that of *Balangu*. However in *Tukunya*, the sizeable cuts of meat are spiced up with all ingredients including vegetable oil, needed for its preparations. It is then wrapped in wet brown paper or old newspaper before it is placed over a hot red glow on a wire mesh to roast slowly and turned from time to time.

2.4.4 *Kilishi*

Kilishi is made by roasting spiced, salted slices or strips of meat (usually beef), but different from *Suya* in that a two-stage sun-drying process proceeds roasting. Consequently, *kilishi* has lower moisture content than*suya* and a longer shelf life. *Kilishi* consists of about 46% meat and about 54% non-meat ingredients, with defatted peanut powder accounting for about 35% of the ingredient formulation (Aworh, 2008).

Iheagwara and Okonkwo (2016) reported moisture content of *Kilishi* samples to range from 10.02% - 12.02%, while moisture values of 6.92%, 9.87% and 10.00% were reported by Jones *et al.* (2001), Apata *et al.* (2013) and Olusola *et al.* (2012) respectively, but Isah and Okubanjo (2012) reported much higher values of 19.75 – 23.30% and likewise Raji (2006) with values of 19-26%. For crude protein, Iheagwara and Okonkwo (2016) stated protein content of *Kilishi* samples to range from 51.62% to 55.84% which was quite similar with regards to the values (53.41%-64.53%) reported by Isah and Okubanjo (2012). Igene *et al.* (1990) reported a value of 50.02% while Ogunsola and Omojola (2008) in their own studies had values which ranged from 33.88 to 60.33%.

For ether extract, Iheagwara and Okonkwo (2016), reported fat content of their kilishi samples to have ranged from 17.34% to 19.20% which corresponded with values of 17.8% reported by Igene *et al.* (1990). Jones *et al.* (2001) reported a fat content as high as 25.36%. For ash content, Iheagwara and Okonkwo (2016), reported ash content of *Kilishi* samples to have ranged from

4.54% to 5.58% which was close to that reported by Ogbonnanya and Linus (2009) at 5.71%. Ogunsola and Omojola (2008) had an ash content range of 6.96 to 8.78 %. In their study, the ash content of the final *Kilishi* from beef and pork differed significantly from that of the raw dried meat. An ash content of 6.72 was reported by Jones *et al.* (2001) while Igene *et al.* (1990) and Iheagwara and Okonkwo (2016) reported values of 9.6% and 4.54% to 5.58% respectively. A similar range of 4.98 to 9.43% was reported by Isah and Okubanjo (2012). Abubakar *et al.* (2011) in their work on *suya*produced from ruminants, reported *kilishi* protein content to range from 49.9-57.1% ,while their ether extract values ranged from 25.2- 27.0% and ash value was 5.4-7.3%. Their work also reported values of 30.64, 10.33, 22.33 and 7.67% respectively for protein, moisture, fat and ash contents respectively.

2.4.5 *Suya*

In *suya* preparation, lean meat obtained from semi-membranous muscles of cattle, camel, sheep and goats are cut into pieces and then further sliced into thin sheets with the aid of a sharp knife. The sliced sheets of meat are then staked on iron rods or skewing sticks before being heavily dusted with spices and ingredients. The staked meat dusted with spices are then placed either on wire mesh to grill or fixed into the soil around a fire or glowing charcoal to roast. The roasting is done on a local tukuba (a clay mold heap that has a hole within where the firewood is burnt into hot red charcoals) (Uzeh *et al.*, 2006; Balarabe, 2016).

Edema *et al.* (2008) reported a moisture content range of 40.17 to 57.17% and pH range of 8.28 to 9.07. Igene and Abulu (1983) reported moisture content in unroasted *suya* to vary from 67.5 to 70.5%, while the level in the roasted products varied from 20.7 to 26.8%. For ash contents, they reported that the roasted products were higher (0.7 to 3.1%) than the ash content in unroasted (0.9 to 1.6%) products. The level of protein varied from 19.2 to 23.3% in the raw product; following roasting the protein content increased from 56.9 to 60.6%. The fat content in the raw products varied from 6.2 to 10.3%, while in the roasted products fat levels were from 11.4 to 18.4%. Abubakar *et al.* (2011) in their work, reported the dry matter to have ranged from 91.9-92.6% while the crude protein was between 49.8-53.6%, ether extract values ranged from 12.1-13.3% and ash values were 7.3-8.1%. Egbebi and Seidu (2011) in their work reported moisture values which ranged between 46.50-57.00% while Apata *et al.* (2013) in their work reported moisture values that ranged from 34.20 – 36.05%, crude protein ranged from 38.20-39.61% and fat values were between 12.60-13.48 while ash and crude fibre values ranged between 6.60-8.00% and 1.01-1.36% respectively; lipid oxidation and pH values were reportedly between 0.50-0.78 and 5.93-6.82 respectively.

2.5 Review of Physicochemical Properties of Processed and Stored Meat Products

Oyadeyi *et al.* (2014) in their study noted that the moisture content (MC) of *Suya* that was not soaked in *Occimum gratissimum* extract to be 48.03% and it was significantly higher ($P<0.05$) than the other treatments which were soaked in *O. gratissimum* extract for the periods of 30mins, 60mins, 90mins and 120mins. Treatment which received 120mins of soaking in the extract gave the lowest mean MC value of 45.93%. On crude protein, they reported a range of 32.96 to 33.86%, with the least being the treatment which was not soaked in *O. grattisimum* and the highest being in that which was soaked for 90mins. They further reported an ether extract range of 7.96%(treatment soaked for 30mins) to 8.70% (treatment soaked for 60 mins) and an ash range of 4.93%(treatment soaked for 120mins) to 5.56%(treatment not soaked in extract). These values however varied over storage duration of seven days.

Isah and Okubanjo (2012) reported that there was significant difference in moisture contents amongst six *Kilishi* treatments which were prepared with five different spices; clove, nutmeg, black pepper, alligator pepper, and ginger, which were combined in one treatment and individually absent in the other five treatments. They further reported that the ether extract content of the *Kilishi* ranged from 8.95% in *Kilishi* without black pepper to 10.13% in *Kilishi* without cloves, while the raw dried meat had a value of 2.40% ether extract. Significant difference however, occurred in the crude protein content of the raw meat and the final Kilishi products. Highest crude protein value (73.74%) was observed in the raw dried meat while the crude protein content of the various *Kilishi* products ranged from 53.41% in *Kilishi* without black pepper to 64.53% in *Kilishi* with all the spices.

According to Sodzim (2012), a significant difference (5.53-6.80) in pH values amongst all the pork treatment on a 9-day storage period at room temperature(23 ºC) compared favourably with Jałosińska and Wilczak (2009) with reports of very small (5.96-6.08) pH change as well in their meat ball treatments over a 16-day storage period at 10ºC. Oyadeyi *et al.*(2014) also reported significant differences ($P<0.05$) amongst all their *Suya* treatments on a 7-day storage period at room temperature. Moisture content reportedly declined from 45.33% to 39.50% and crude fibre values showed no changes all through the storage days. Protein however increased from 33.66% on day 1 to 36.66% by day 7 and this trend followed with ash (5.56-5.76%) and ether extract (8.70 – 8.90%). However, Igene *et al.* (2016) in their work on stored *Kilishi* for over 6months, reported significant increase in moisture content from 10.4% at the beginning to 12.1% at the end.

Also Haruna (2014), who worked on chicken nuggets, reported significant differences in pH and TBARS values across all treatments as the storage days increased.

2.6 Organoleptic Properties of Meat Products

2.6.1 Sensory evaluation

Sensory evaluation has been defined by Stone and Sidel (2004) and the Institute of Food Technologists (IFT) (2007) as "a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing". Sensory evaluation is a common and very useful tool in quality assessment of processed meat products. It makes use of the senses to evaluate the general acceptability and quality attributes of the products. Processed meat products have attributes that appeal to the senses and that is what promotes its consumption and popularity among consumers. The eating quality of meat is a function of the animal production and carcass processing that has been applied. One way by which these products are properly assessed scientifically is through sensory evaluation. Sensory or organoleptic qualities of meat are determined by sensory characteristics relating to colour, texture, aroma, flavour and juiciness and these are influenced by a number of factors including pre-slaughter handling, muscle composition, post slaughter biochemical reactions and technological factors (Nasir *et al.*, 2011).

These factors combine to give an overall assessment of meat quality by the ultimate arbiter, the consumer. The critical point of appraisal of meat quality occurs when the consumer eats the product, and it is this outcome, together with views of colour, healthiness and price, that determine the decision to re-purchase (Boleman *et al.*, 1997). Meat quality evaluation is important in improving meat production (Barbera and Tassone, 2006). Texture, aroma and flavour characteristics are the main criteria used by consumers to evaluate the sensory quality of meat (Gorraiz, *et al.*, 2000). These sensory attributes can be measured objectively by a trained panel, using descriptive techniques. Descriptive sensory evaluation addresses the complexity of food systems by considering as much food sensory attributes or flavour notes as possible (Brovelli *et al.*, 1999). Descriptive methods focus on the intensities of sensory characteristics of a product such as aroma, juiciness, flavour and tenderness (Lawless & Heymann, 1998).

Sensory analyses are sophisticated tools and are often the final step in the evaluation of various treatments of meat and other food products (Lawless & Heymann, 1998). Sensory analyses form an essential part in determining the quality of meat and profiling of food because these sensory factors of taste, aroma and texture contribute to the palatability of meat (Nevison and Muir, 2002). Results obtained during sensory evaluation can provide valid and reliable information with regard to a product's sensory properties (profile).

2.6.2 Meat Colour

The optical appearance of food is important for the consumer. The color of food surface is the first quality parameter evaluated by consumers, and it is critical to product acceptance (Tanner, 2016). Food appearance determined mostly by surface color is the first sensation that the consumer perceives and uses as a tool to either accept or reject food (Leon *et al.*, 2006). Under normal circumstances, the colour of meat is in the range of red and may differ from dark red, bright red to slightly red; but also pink, grey and brown colours may occur. In many cases, the colour indicates the type and stage of the treatment to which the meat has been subjected, as well as the stage of freshness. After cooking, meat color can turns grey or brown because oxymyoglobin is not heat stable.

In judging meat colour, some experience is needed to be able to distinguish between the colour which is typical for a specific treatment or which is typical for specific freshness. Furthermore, meat derived from different species of animals may have rather different colours, as can easily be seen when comparing beef, pork and poultry meat (FAO, 1999). Remarkable changes in the meat colour occur when fresh meat has been boiled or cooked. It loses its red colour almost entirely and turns to grey or brown (FAO, 1999). The reason for this is the destruction of the myoglobin through heat treatment. This is the typical colour shown in sausages of all types, raw and cooked hams, corned beef, etc. (FAO, 1999). Cured products with a decreasing keeping quality can be recognized when the red colour becomes pale or changes to grey or green.

2.6.3 Meat Tenderness

Tenderness is defined by the ease of mastication, which involves initial penetration by the teeth, the breakdown of meat into fragments and the amount of residue remaining after chewing (Lawrie, 1998; Kassim,2013). Safari *et al.* (2001) noted that the most important contributing sensory attributes to eating quality are tenderness, flavor and juiciness.

Tenderness is an integrated textural property composed of mechanical and chemical components. The mechanical characteristics include hardness, cohesiveness, elasticity, grittiness and fibrousness while the chemical characteristics include juiciness and oiliness (Brewer and Novakofski, 2008). Tenderness has also been shown to depend positively upon intramuscular fat

(Aaslyng and Stoier, 2004). Tenderness is the first and foremost quality that is sought in meat, irrespective of the methods of cooking. Tenderness remains the main criterion for judging quality. Since flavour and juiciness are less variable and can be compensated for by liberal use of gravies, seasonings and vegetables. The fact is that tenderness actually improves the remaining quality characteristics.

Factors affecting muscle and meat tenderness have been extensively researched over the past 70 years and according to Dransfield (2001), tenderness is the primary determinant of the acceptability and eating quality of meat. Meat tenderness is a very complex characteristic of meat quality, as it is biologically dependent on factors such as species, age, fat code, gender, the retail cut chosen, the method of cooking, and muscle type (two protein fractions, namely connective tissue and myofibrillar properties) (Dransfield, 2001). Furthermore, tenderness has also been shown to depend positively upon intramuscular fat (Aaslyng and Støier, 2004; Kassim 2013) and ageing (Wheeler and Koohmaraie, 1994; Kassim 2013), and negatively on the amount of connective tissue (Honikel, 1992; Kassim 2013).

2.6.4 Meat Flavour/Aroma

Flavour is an important sensory characteristic for the overall acceptability of meat products. Aroma is the most important component, because of the nasal receptor for numerous volatile components released during chewing and ingestion. Flavour is the feature that convinces the consumer to buy the product again. The sensation of flavour is the result of a combination of responses on the tongue, and in the mouth, throat and nose (Woods, 1998). Flavour is a complex sensory reaction involving taste, smell (odour) and texture of a product. Odour or aroma is the most important component, because of the nasal receptor for numerous volatile components released during chewing and ingestion. The number of aroma compounds derived from the spices and smoking exceeds that of the compounds derived from metabolism (Schimdt and Berger, 1998; Kassim, 2013).

Flavour is experienced during mastication when volatiles are released in the oral cavity and aroma is perceived by the olfactory system. Flavour is generated from reactions of various flavour precursors including reducing monosaccharides and inosine monophosphate (IMP) during heating (Mottram and Madruga, 1994; Kassim 2013). Flavour is mainly generated during the heating process and the Maillard reactions involving reducing carbohydrates and amino acids are one of the most important routes to flavour formation (Mottram, 1998; Kassim, 2013). Reports have shown that cooking process in relation to flavour formation is significant and temperature is of major importance. Wood *et al.* (1995; Kassim 2013) showed that pork flavour increased as the core temperature of grilled steaks increased from 65ºC to 80 ºC, while both juiciness and tenderness simultaneously decreased.

2.6.5 Meat Juiciness

Juiciness is the feeling of moisture in the mouth during chewing. It is a dynamic attribute changing during the chewing process (Aaslyng, 2002). Juiciness is an important factor in sensory evaluation as it facilitates the chewing process as well as brings the flavour component in contact with the taste buds (Aaslyng *et al.*, 2002). The two sensory descriptive words for juiciness, in cooked meat, are initial and sustained juiciness (Lyon and Lyon, 1989). Initial juiciness is the amount of fluid released by the cut surface of meat, during compression between the forefinger and thumb (AMSA, 1995). Sustained juiciness is described as the perceived juiciness after a few seconds of mastication, due to the presence of intramuscular fat stimulating saliva secretion (Lawrie, 1998, Kassim 2013). The content of intramuscular fat is positively correlated to juiciness (Cummings *et al.*, 1999; Brewer *et al.*, 2001). The juiciness of meat depends on the raw meat quality and the cooking procedure (Aaslyng *et al.*, 2002). Other factors like concentration of glycogen could also influence the juiciness as an increased concentration of glycogen have been reported to increase the juiciness in beef with a normal pH between 5.5 and 5.75 (Immonen *et al.*, 2000).

2.7 Effects of Processing Methods on Organoleptic Properties of Meat

Smoking at high temperature has being reported to cause a toughening of meat fibres due to heat coagulation and shrinkage of the myofibrillar proteins and connective tissues. Initial toughening is due to protein denaturation which occurs when the meat reaches 50-80^{o}C, this is followed by some tenderization which occurs as collagen hydrolyses to gelatin at temperatures greater than 75^{0}C (Inneke, 2011). However, prolonged heating can increase the tenderness due to the conversion of collagen to gelatine by heating. Gandi (2014), reported mean sensory score on a five point hedonic scale for meat smoked with *Acacia raddiana, Eucalyptus camaldutensis, Neem* and coconut shell. Mean values obtained for colour showed meat smoked with *Acacia* and *Eucalyptus* to have had the highest values of 2.60 each which were statistically similar to meat smoked with *Neem* (2.35), but differed from meat smoked using coconut shell (1.57). Values obtained for juiciness showed highest mean in meat smoked with *A. raddiana* (2.85) which was statistically same with meat smoked using *Neem* (2.65) and *Eucalyptus* (2.30) but differed significantly (P<0.05) from meat smoked using coconut shell (1.40). Taste was highest in meat smoked using *Neem* (2.85) while that smoked using *Acacia* was (2.30) and this was statistically similar to meat smoked using *eucalyptus* (2.05) and coconut shell (1.50). For flavour there was difference across treatment with the lowest value was observed in meat smoked using coconut shell (2.00), and the highest was observed in meat smoked using *acacia* (2.85%). However he reported that values obtained for overall acceptability were not significant.

Kassim (2013) noted these on the organoleptic characteristics of meat floss prepared from different meat types when frying is involved. She reported that there were no significant difference ($P>0.05$) in the aroma of all the meat floss from pork, beef and chevon with values ranging from 3.55 to 4.22. Pork floss had highest values in terms of aroma, flavour, tenderness, juiciness and texture compared to that of chevon floss and beef floss. There was no significant difference ($P>0.05$) between beef floss and chevon floss for aroma, tenderness, juiciness and texture. The result obtained showed that roppiness was adjudged similar ($P>0.05$) for the meat floss from the three meat samples while the panelist gave higher score (7.44) to beef meat floss, 6.56 to chevon meat floss and 6.22 to pork meatfloss in terms of overall acceptability.

For grilling, Adeyeye (2016) reported mean sensory score on a nine-point hedonic scale for meat grilled with Traditional *Suya* Smoker (TSS), Electric Grilling Machine (EGM) and Hot Air Oven(HAO). He reported that *suya* processed from TSS had the highest value of 8.59 in terms of overall acceptability while that from EGM had the least overall acceptability value of 6.42. For taste, TSS *suya* had the highest taste value of 8.61 followed by that from EGM, 7.83 while the *suya* sample from HAO had the least value of 6.62. For juiciness, *suya* sample from EGM had the highest value 7.71, followed by *suya* sample from TSS 7.22, while *suya* sample from HAO had the least value 6.48. For appearance, *suya* sample from HAO had the highest value 7.68, followed by *suya* sample from EGM (7.47), while the sample from TSS rated least (6.93). Similar results were obtained for texture and color.

2.7.1 Effects of Herbs and Spices on Organoleptic Properties of Processed Meat Products

Isah and Okubanjo (2012) reported that in terms of flavor,*Kilishi* where alligator pepper was absent was most preferred. However for juiciness, *Kilishi* that had no black pepper and alligator pepper was most preferred. In the case of tenderness, they observed that *Kilishi* that had no clove, black pepper and nutmeg were adjudged to be similar to the control which had all six spices present and as such concluded that the three spices could be omitted from *Kilishi* slurry without much effect on the tenderness of the final products. Their overall conclusion was that one or two of the spices could replace each other without any marked difference in flavor, juiciness, pungency, tenderness and overall acceptability.

Haruna (2014) who worked on different spices (cloves, ginger, pepper, black pepper and African nutmeg) to determine their antioxidant and antimicrobial activities on chicken nuggets reported that lipid oxidation of chicken nuggets was improved by the inclusion of spice extracts with cloves, ginger, pepper and their combinations performing better than the other spices. Furthermore, Oyadeyi *et al.* (2014) inferred that meat patties of beef and chevon cured with *Ocimum gratissimum* extract for 1 hr and 1½ hrs gave better overall acceptability while control and ½ hr soaked pork patties were preferred to patties from other curing times. They also observed that the overall acceptability of *ocimum* cured beef, chevon and pork patties rating showed that treatment cured at ½ hr, 1 hr and 1½ hrs were different with different mean values range of 6.81 (Beef), 6.11 (Chevon) and 5.89 (Pork) while treatment cured at 2hrs had the least mean values with least acceptance. They concluded that according to the rating of the panelist, the taste was more appreciated in patties cured for ½ hr and 1 hr in *Ocimum* extract.

In another study conducted by Newman *et al.* (2018), the results showed that the use of *Xylopia aethiopica* and *Monodora myristica* in the formulation of fresh pork sausage had no significant effect on the sensory characteristics of the finished product. They however noted higher preference generally by sensory panelists to the Negro pepper formulated fresh pork sausage.

2.8 Review of Microbial Effects on Processed Meat Products

Microorganisms are living creatures that are microscopic in size and are heterogeneous organisms that can be in form of plant or animal such as algae, fungi (mould and yeasts), and bacteria (Wikipedia, 2011). The spoilage of meat occurs if the meat is untreated in a matter of hours or days and results in the meat becoming unappetizing, poisonous or infectious (Lawrie, 1990). Spoilage is caused by the practically unavoidable infection and subsequent decomposition of meat by bacteria and fungi, which are borne by the animal itself, by the people handling the meat and by their implements. Meat can be kept edible for a much longer time though not indefinitely if proper hygiene is observed during production and processing and if appropriate food preservation and food storage procedures are applied (Lawrie and Ledward, 2006). The organisms spoiling meat may infect the animal either while still alive (endogenous disease) or may contaminate the meat after its slaughter (exogenous disease).

The bacteriological condition of carcass meat is highly dependent on the manner, in which meat animals are reared, slaughtered and processed as resulting meat products is strongly influenced by the prevailing hygiene condition during their production and handling (Osama and Gehan, 2011). The carcass of a healthy animal slaughtered for meat and held in a refrigerated room is likely to have only minimal surface bacteriological contamination while the inner tissues are sterile. After chilling, further processing of beef carcasses can result in product contamination.

When carcasses and cuts are subsequently handled through the food distribution channels where they are reduced to retail cuts, they are subjected to an increasing number of micro-organisms from the cut surfaces (Okonko *et al.*, 2010). Contamination subsequently occurs by the introduction of micro-organisms on the meat surfaces in operations performed during cutting, processing, storage, and distribution of meat (Clarence *et al.*, 2009). However, if the meat is kept clean by preventing contamination through dirty hands, clothing, equipment and facilities and the meat is kept cold and covered, there will be little or no contamination by micro-organisms whether bacteria, yeasts, moulds, viruses or protozoa (Osama and Gehan, 2011). Fresh meat cut from the chilled carcasses has its surface contaminated with micro-organisms characteristic of the environment and the implements used to cut the meat (Biswas *et al.*, 2011).

Employees are the largest contamination source and employees who do not follow sanitary practices, contaminate food that they touch with spoilage and pathogenic microorganisms. Employees come in contact with these micro-organisms through work and other parts of the environment while their hands, hair, nose and mouth, harbor microorganisms that can be transferred to food during processing, packaging, preparation and service by touching, breathing, coughing or sneezing (Cohen *et al.*, 2006; Selvan *et al.*, 2007; Biswas *et al.*, 2011). Therefore, in the prevention of meat contamination, personal hygiene plays an important role as there are as many as 200 different species of microorganisms on a healthy human body (Featherstone, 2003). Carcass contamination not removed by trimming or washing at slaughter is spread to newly exposed surfaces, which in turn can potentially decrease the shelf life of retail cuts and ground beef in retail meat display cases (Stivarius *et al.*, 2002; Marriot, 2004). The process of chopping and grinding enables bacteria present on the meat surface, to be distributed throughout the product (Siriken, 2004; Salihu *et al.*, 2010).

Spoilage organisms produce chemical reactions that cause offensive sensory changes in foods and are mediated by a variety of microbes that use food as a carbon and energy source. These organisms include prokaryotes (bacteria), single-celled organisms lacking defined nuclei and other organelles, and eukaryotes, single-celled (yeasts) and multicellular (molds) organisms with nuclei and other organelles. Some microbes are commonly found in many types of spoiled foods while others are more selective in the foods they consume. Multiple species are often identified in a single spoiled food item but there may be one species (a specific spoilage organism, SSO) primarily responsible for production of the compounds, causing off-odours and flavours (Ellin, 2007). Within a spoiling food, there is often a succession of different populations that rise and fall as different nutrients become available or are exhausted. Gram *et al.*, (2002) observed that some microbes, such as lactic acid-bacteria and moulds secret compounds that inhibit competitors. Meat spoilage by micro-organisms can manifest itself as highlighted in Table 2.2.

Osho (2004) evaluated the bacteria contamination of *Suya* processed in Abeokuta South western Nigeria and found up to 10^3 cfu / g enterobacteriaceae in 40% of the samples collected; more than 10^4 cfu / g aerobic mesophiles including Staphylococcus aureus in all collected samples. Inyang *et al.* (2005) also evaluated the bacterial quality of *Suya* sold in Markurdi, Northern Nigeria and

Table 2.2: **Symptoms of Microorganisms found in Meat**

Oxygen	Microbial agent	Symptoms

g.

Present	Aerobic bacteria	Surface slime
		Discoloration
		Gas production
		Change in odor
		Fat decomposition
Present	Yeast	Surface slime
		Discoloration
		Change in odor and taste
		Fat decomposition
Present	Mold	Sticky and “whiskery”surface
		Discoloration
		Change in color
		Fat decomposition
Absent	Anaerobic bacteria	Putrefaction and foul odors
		Gas production
		Souring

Source: Lawrie (2003).

concluded that feacal coliforms were the main bacterial contaminants although they occurred within acceptable limits (less than 10^4), although the total bacterial counts were more than 10^6 cfu / g.

Aworh *et al.* (1998), reported high levels of contaminating microorganisms were present in *suya* with aerobic counts, yeasts and molds exceeding 10^6. This is consistent with previous reports on the microbiological quality of *suya* (Igene and Abulu, 1984). This they attributed to unsanitary processing environment and poor quality ingredients, especially the spices used for *suya* preparation, contribute to the high microbial load of *suya*.

2.9 Spices and their Effects on Meat Quality and Shelf-Life

Over the years, plant extracts and plant-derived medicines have made an immense contribution to the overall health and wellbeing of man (Anyanwu and Nwosu, 2014). In 1978, World Health Organization (WHO) emphasized the importance of scientific research into herbal medicine as herbs are generally valued for their virtues as food as well as medicine. Plants have the ability to synthesize a wide variety of chemical compounds that are used to perform important biological functions and to defend against attack from predators such as insects and microbes. The study of plant extracts as food preservatives has led to the discovery of food additives that have immense contribution to the overall health and wellbeing of man. The use of these plants as spices and preservatives in foods is due to the presence of bioactive constituents such as phenols, flavonoids, tannins, alkaloids etc., present either in the seeds, leaves, stems or roots (Tapsell, 2006) and its especially of value here in Nigeria, where the incessant power outage has made cold storage non-realistic.

The Geneva-based International Standards Organisation (ISO) defines spices and condiments as: Vegetable products or mixtures thereof, free from extraneous matter, used for flavoring, seasoning and imparting aroma in foods. Spices include all parts of herbaceous plants except the leaf, which is considered an herb. Webster dictionary describes spices as ‘Any of various aromatic vegetable productions as pepper, cinnamon, nutmeg, mace, allspice, ginger, cloves, etc., used in cookery to season and to flavor sauces, pickles, etc.; a vegetable condiment or relish, usually in the form of a powder; also, as condiments collectively'.

Author Rosengarten (1969) in 'The book of spices'defined a spice as a product which enriches or alters the quality of a thing, for example altering the taste of a food to give it zest or pungency; a piquant or lasting flavoring; or a relish. The term 'spice' is thus used to cover the use of spices, herbs and certain aromatic vegetables to impart odor and flavor to foods. A conventional classification of spices is based on degree of taste as:

- Hot spices e.gs Capsicum (chillies), Cayenne pepper, black and white peppers, ginger, mustard
- Mild spices; examples includes Paprika, coriander.
- Aromatic spices e.gs includes Allspice (pimento), cardamom, cassia, cinnamon, clove, cumin, dill, fennel, fenugreek, mace and nutmeg.
- Herbs e.gs includes Basil, bay, dill leaves, marjoram, tarragon, thyme
- Aromatic vegetables e.gs includes Onion, garlic, shallot, celery.

Though the term spice can be used to incorporate herbs, the distinction between herbs and spices can be described as follows:

- Herbs may be defined as the leafy part of aromatic plants used to impart flavour and odour to foods with, sometimes, the addition of colour. The leaves are commonly traded separately from the plant stems and leaf stalks while spices are parts of the plant other than the leafy bit such as the root, stem, bulb, bark or seeds or the non- leafy parts. Thus the difference in the two is where they are obtained from in a plant. Spices generally are parts of various plants cultivated for their aromatic pungent or otherwise desirable substances. They consist of rhizomes, bulbs, flower bud, fruit, seed, and leaves. They usually are categorized into tiny wild fruits, nuts, herbs, and leafy vegetables (Peter, 2001).

Herbs and spices are not just valuable in adding flavour to foods. Their antioxidant activity also helps to preserve foods from oxidative deterioration, increasing their shelf life. There has been increasing research in the role of herbs and spices as natural preservatives. As an example, ground black pepper has been found to reduce the lipid oxidation of cooked pork. Antioxidants also play a role in the body's defence against cardiovascular disease, certain (epithelial) cancers and other conditions such as arthritis and asthma. Phenolic compounds such as flavonoids may help to protect against cardiovascular disease and intestinal cancer (black pepper, oregano, thyme and marjoram). Gingerol in ginger is also an intestinal stimulant and promoter of the bioactivity of drugs. Capsaicin in chilli pepper is an effective counter-irritant used in both pharmaceuticals and cosmetics. Fenugreek, onion and garlic help lower cholesterol levels. A number of spices have also been identified as having antimicrobial properties. Studies in the past decade confirm that the growth of both gram-positive and gram-negative foodborne bacteria, yeast and mold can be inhibited by spices. Some of the spices that aid in these activities arecloves (*Eugenia aromatica*), ashanti pepper (*Piper guineense*) and negro pepper (*Xylopia aethipica*).

2.9.1 Cloves (*Eugenia aromatica*)

Eugenia aromatica is synonymous to *Syzygium aromatucum* or *Eugenia caryophyllata.*In Nigeria , it is known as *Kanumfari* by the Hausas,*Kanafuru* by the Yorubas and *kloovu/ ncharra* by the Igbos. A picture of cloves is seen in Fig. 3.2. The word clove is derived from 'clou' which means nail. It is a native from the Maluku islands in east Indonesia but also grown in Zanzibar, Madagascar, India and Sri Lanka (Kamatou *et al.*, 2012). It is an aromatic flower of a tree in the family Myrtaceae. Clove tree is an evergreen tree of median size whose height ranges from 8-12m. The bark of the tree is gray whereas the leaves are dark green, elliptical, fragrant and shiny in appearance.

The clove tree is frequently cultivated in coastal areas at maximum altitudes of 200 m above the sea level. The production of flower buds, which is the commercialized part of this tree, starts after 4 years of plantation. Flower buds are collected in the maturation phase before flowering. The collection could be done manually or chemically-mediated using a natural phytohormone which liberates ethylene in the vegetal tissue, producing precocious maturation (Filho *et al.*, 2013).

Cloves spice contains essential oil (up to 15%), whose constituents are eugenol, eugenol acetate and β-caryophyllene. 100g of ground cloves contain 0.144g water, 6.783kcal energy, 0.126g protein, 0.123g ash and 0.421 total fat/lipid. Clove main antimicrobial chemical ingredient eugenol, the phenol compound also found in cinnamon, makes up the majority of clove bud oil, at 60-90%(Livestrong, 2010). Suleiman and Anas (2017), reported the proximate composition of the buds to have 85.2 % dry matter, 14.8% moisture content, 12.6 % ash content, 16.2 % crude fat, 12.4% crude protein, 17.5 % crude fibre and 41.3% total carbohydrate. Bello and Jimoh (2012), also reported values on the proximate composition of clove buds to have moisture 23.4%, ash 9.10%, crude fibre 10.65%, crude fat 18.90%, crude protein 7.00%, and carbohydrate 30.95%. Ogunka-Nnoka and Mepba (2008), reported the proximate values of clove to contain moisture 12.1%, crude protein 7.8%, lipid 9.3%, total carbohydrate 68.6% crude fibre1.1% and ash 1.1%, while Olusola *et al.* (2012) reported cloves to have 12.38% moisture, 5.43% crude protein, 7.37% ether extract, 9.47% crude fibre, 5.60% ash and 59.75% total carbohydrate.

The antimicrobial activities of clove have been proved against several bacterial and fungal strains. Sofia *et al.* (2007) tested the antimicrobial activity of different Indian spice plants as mint, cinnamon, mustard, ginger, garlic and clove. The only sampled that showed complete bactericidal effect against all the food-borne pathogens tested *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus* was the aqueous extract of clove at 3%. At the concentration of 1% clove extract also showed good inhibitory action.

The antibacterial activity of clove, oregano (*Origanum vulgare*), bay (*Pimenta racemosa*) and thyme (Thymus vulgaris) essential oil was tested against E. coli O157:H7 showing the different grades of inhibition of these essential oils (Burt and Reinders, 2003). Likewise formulations containing eugenol and carvacrol encapsulated in a non-ionic surfactant were tested against four strains of two important foodborne pathogens, E. coli O157:H7 and Listeria monocitogenes, results reinforces the employment of eugenol to inhibit the growth of these microorganisms in surfaces in contact with food (Pérez-Conesa *et al.*, 2006).

Pure clove oil or mixes with rosemary (*Rosmarinus officinalis spp*.) oil were tested against Staphylococcus epidermidis, Staphylococcus aureus, Bacillus subtilis, E. coli, Proteus vulgaris, Pseudomonas aeruginosa and results showed minimum inhibitory concentrations between 0.062% and 0.500% (v/v) which is promising as anti-infectious agents or as food preservative (Fu *et al.*,2007).

Snyder (2012) reported cloves to have a strong inhibitory effect against microbes and are able to kill species of bacteria and fungi such as *S. aureus, L. monocytogenes*, and *Aspergillus.* A study performed by Barbosa *et al.* (2009) compared the essential oils of clove, lemongrass, basil, oregano, ginger, marjoram, and thyme through an agar dilution method and a minimum inhibitory concentration test. The oils were tested against two Gram-positive bacteria, S. aureus and *L. monocytogenes*, and two Gram-negative bacteria, *E. coli* and *S. enteritidis*. The clove essential oil had the highest antimicrobial activity out of all the spices tested (Barbosa *et al.*, 2009). Leuschner and Lelsch (2003), tested ground clove, fresh garlic, and red dried chili in broth at two temperatures against *L. monocytogenes*. Once again, the clove's antimicrobial properties proved to be the most effective at killing the bacteria (Leuschner and Lelsch, 2003). Beta-cyclodextrin inclusion mucomplexes containing eugenol and clove bud extracts were tested against two common foodborne pathogens, Salmonella enterica serovar Typhimurium LT2 and Listeria innocua (Hill *et al.*, 2013). Clove products have a great potential as food additives since they are very effective and for being natural products are preferred for consumers.

2.9.2 Ashanti pepper (*Piper guineense*)

Katzer and Gernot (2015) reported Ashanti pepperto be a spice plant from the family Piperaceae and from genus piper. It is a West African spice plant commonly called Ashanti pepper. It is known as *Uziza* in Igbo, *Masoro* in Hausa and *Iyere* in Yoruba. Other common names are Benin pepper, Guinea pepper and false cubeb (Katzer and Gernot, 2015). A picture of Ashanti pepper is seen in Fig. 3.3.

The plants that provide Ashanti pepper are vines that grow up to 20m tall climbing up bole of trees by means of adventitious roots. It is a perennial plant that is characterized by heart-shaped leaves and oval, petiole, alternate, 12cm long. The leaves which have a peppery taste, are pale greenish color when fresh and darker green when frozen or dried. The fruits of Ashanti pepper occur in clusters, small, reddish or reddish brown when ripe and black when dry (Okwute,1992). The fruit is a drupe mesocarp or fleshy, oval, 5mm in diameter.

The plant is native to tropical regions of central and Western Africa and is semi-cultivated in countries like Nigeria where it is found commonly in the southern part (Dalziel, 1955). It grows in evergreen rainforest, forest edges, usually in wet places, gallery forest along rocky rivers of an elevation of 750-1,650m. There are more than 700 species of this plant throughout tropical and subtropical regions of the world (Anyanwu and Nwosu, 2014). This plant has so many uses including culinary, medicinal, cosmetic and insecticidal uses (Dalziel, 1955; Martins, 2013).

Nwankwo *et al.* (2014) reported Ashanti pepper to have nutritional and non-nutritional factors which are responsible for its aroma, flavor, and preservative properties with proximate analysis revealing that the plant contains crude protein, fat, carbohydrate, vitamins and minerals. Igile *et al.* (2013) also studied Uziza Leaf and found that in addition to the above mentioned, it also contains a high amount of ash. Ndulaka *et al.* (2016) reported that Ashanti pepper contained 6.23% protein, 10.20% fat, 0.23% fiber, 0.43% ash, 0.17% carbohydrate, 82.43% moisture and 84.14 dry matter. Ebana *et al.* (2016), reported moisture content of Ashanti pepper seeds to contain 14.15% moisture, 1.85 % ash, 11.42% protein, 8.40% fat, 7.75% fibre, 70.42% carbohydrate. Okeke *et al.* (2018) reported value range of 7.67-12.62% for protein, 48.57-54.31% for carbohydrate, 4.51-10.33% for ash, 6.39-9.17% for crude fat, 11.13-13.61% for moisture, 8.26- 11.04 for crude fibre and 82.20-91.30% for dry matter.

The seeds of Ashanti pepper are used in Western African cuisine where it imparts ”heat” (piquantness) and a spicy pungent aroma to soups and stews (Katzer and Gernot 2015). The leaves are also used as to flavor meat preparation and fresh pepper soup. They are also processed and consumed as vegetables in meals (Okigbo and Igwe, 2007). The oil distilled from Ashanti pepperis used in perfumery and in soup making. Anyanwu and Nwosu (2014) reported on the antimicrobial activity of aqueous and ethanolic extracts of Ashanti pepper leaves on some bacterial and fungal organisms namely *Staphylococcus aureus, Escherichia coli, Pseudomonas aueroginosa, Candida albicans* using Agar Well Diffusion method and Minimum Inhibitory Concentration. Their result showed that the leaf extracts of *P. guinnense* inhibited the growth of all the microbial isolate tested. This implies that the leaf extract has antimicrobial action. The extracts had a broad spectrum activity as their actions were independent of gram reaction. The higher antimicrobial activity of the extracts was observed against *E. coli* followed by *S. aureus.* The antimicrobial effect of this plant can be attributed to the phytochemicals present in it, they are rich in flavonoids, tannins, saponins and alkaloids which have been found to have antimicrobial properties. The study showed that the aqueous extract of Ashanti pepper has less antimicrobial activity than the ethanolic extract against the isolates (Anyanwu and Nwosu, 2014).

Mouafo *et al.* (2012) in their study of aqueous and ethanol extracts of *O. gratissimum* and Ashanti pepper leaves which were screened for antibacterial activity against *E. coli* and Staph. Aureus, reported that both extracts exhibited selective inhibition against the isolates. Omodamiro and Ekeleme (2013) studied the antioxidant activity of Ashanti pepper and reported that the leaves of this plant exhibited free radical scavenging effects. This could be attributed to the presence of phenolic compounds in the plant which is a major group of compounds that act as primary antioxidants or free radical scavengers.

2.9.3 Negro Pepper (*Xylopia aethiopica*)

Xylopia is Greek (‘xylon pikron’) for ‘bitter wood’, while aethiopica refers to its Ethiopian origin. Local names are: Arabic (hab al-zelim, fulful as-Sudan); English (negro pepper, grains of Selim, kani pepper, moor pepper, West African pepper tree, senegal pepper); French (noir de Guinée, poivre de Sénégal, graines de Selim); German (mohrenpfeffer, kanipfeffer, selimskörner, Senegal pfeffer, negerpfeffer); Portuguese (pimenta-da-áfrica, pimenta-do-congo); Swahili (mchofu) (Orwa *et. al*., 2009). However in Nigeria, it is known as *Kimba* by the Hausas, *Erunje* by the Yorubas and *Uda* by the Igbos. A picture of this is Negro pepper in Fig. 3.4.

Negro pepper is an aromatic tree which grows up to 15–30 m high and about 60–70 cm in diameter. It is native to the lowland rainforest and moist fringe forest in the savanna zones of Africa, but largely found in West, Central and Southern Africa. These trees are widely distributed in the humid forest zones especially along rivers in the drier area of the region (Orwa *et al.*, 2009). In West Africa, the tree flowers twice annually (March-July and October-December) while fruiting occurs in December-March and June-September.

Negro pepper leaves are simple, alternate, oblong, elliptic to ovate. Its flowers are bisexual, solitary or in 3-5 flowered fasicles or in strange, sinuous, branched spikes, or cymes, up to 5.5 by 0.4 cm and creamy-green. Fruits of *Xylopia aethiopica* look like small, twisted bean-pods which are dark brown, cylindrical, 2.5 to 5 cm long and 4 to 6 mm thick. Each pod houses about 5 to 8 kidney-shaped seeds grains of approximately 5 mm length (Orwa, *et al.*, 2009). Flowers are bisexual, solitary or in 3-5 flowered fasicles or in strange, sinuous, branched spikes, or cymes, up to 5.5 by 0.4 cm and creamy-green. Fruits are small, carpels 7-24, forming dense cluster, twisted bean-like pods, dark brown, cylindrical, 1.5-6 cm long and 4-7 mm thick; the contours of the seeds are visible from outside. Seeds are black, 5-8 per pod, kidney-shaped seeds of approximately 10 mm length with a yellow papery aril. The hull is aromatic, but not the seed itself. The fruit of

Xylopia aethiopica is a slightly hooked cylindrical pod. The matured fruits are usually green but become brownish-black after drying.

According to John-Dewole *et al.* (2012), phytochemical screening of the fruit of *Xylopia aethiopica* confirmed the presence of saponin, saponin glycoside, tannin, balsam, cardiac glycoside and volatile oil. Spectrophotometric analysis for trace metals (such as Mg, Zn, Cu, Ni and Fe), Phosphorus and Sulphur showed that Negro pepper contained Mg (0.370 + 0.002 mg/100g), Zn (1.020 + 0.001 mg/100g), Cu (0.274 + 0.004 mg/100g), Ni (1.099 + 0.001 mg/100g), Fe (0.690 + 0.002 mg/100g), P (30.62 + 0.02 mg/100g) and S (100.50 + 0.51 mg/100g).

Imo *et al.*(2018)reported the chemical composition of Negro pepper fruits, reported it to contain 38.72% fiber, 26.08% carbohydrates, 18.47% protein, 6.73% lipid, 6.02% moisture, and 4.00% ash. Bouba *et al.* (2012) reported the chemical composition of Negro pepper seeds to contain 9.6% moisture, 9.5% ash, 7.9% protein, 33.7% fats and 0.4% NFE. Gbadamosi and Kalejaye (2017) reported the chemical composition of Negro pepper seeds to contain moisture of 10.2%, proteins 19.6%, fats 22.4%, ash 4.5%, crude fibre 12.5%, and carbohydrates 30.8%.

In some African Countries like Nigeria and Cote D'ivoire, the seeds are used in preparation of a type of hot soup given to mothers after childbirth. This is believed to enhance the contraction of uterine wall and also to enhance the expulsion of some remains from the womb. Tatsadjieu *et al.* (2004) reported that the fruit extract could be used as anti-microbial agent against gram-negative and gram-positive bacteria and it is also used in the treatment of rheumatism as well as other inflammatory conditions.

A study by Fleischer *et al.* (2008) showed that the fresh and dried fruits, leaf, stem bark and root bark essential oils in Negro pepper produced various degrees of activity against the gram positive bacteria, *Bacillus subtilis* and *Staphylococcus aureus*, the gram negative bacteria *Pseudomonas aeruginosa* and the yeast-like fungus *Candida albicans*, using the cup plate method. However, none of the oils showed activity against *Escherichia coli*. The medicinal properties were evaluated in-vitro by antimicrobial and antifungal assays. The aqueous and petroleum ether extracts showed growth inhibitory effects on *Staphylococcus aureus* and *Eschericha coli* but *Pseudomonas aeruginosa* and *Saccharomyces cerevisiae* were resistant to the fruit extract and the antibiotic controls. The Minimum Inhibitory Concentration (MIC) on *S. aureus* and *E. coli* were 12.50 mg and 6.25 mg respectively. The Minimum Bactericidal Concentration (MBC) of the crude extract against the test organism ranged from 12.50 mg to 25.00 mg.

2.9.4 Other Spices

Black Pepper/Kalimirch (*Piper nigrum, L*) is the most important, popular and widely used spice in the world, also known as king, among spices. No other spice adds the greatest amount of flavour to the widest range of dishes. For thousands of years, black pepper has been the spice of choice for those who could afford it. Hot, biting and pungent flavour of black pepper makes it the perfect seasoning for almost any food. Piperine is major pungent component of pepper and volatile oil is responsible for the aroma and flavour. It has flavouring, preservative, medicinal (Carminative and febrifuge) properties. Black pepper is suitable for dishes of meat, seafood and eggs. It is used as multifunctional spice, imparting flavour, taste, colour and masking off flavour in foods (Gadekar *et al.*, 2006).

Allspice (*Pimenta dioica*) Allspice takes its name from its aroma, which smells like a combination of spices, especially cinnamon, cloves, ginger and nutmeg. It is grown exclusively in the Western Hemisphere. The evergreen tree that produces the allspice berries is indigenous to the rainforests of South and Central America where it grows wild. Allspice is the dried fruit of the Pimenta dioica plant. The fruit is picked when it is green and unripe and traditionally, dried in the sun. It has a warm and sweetly pungent flavour like the combination described above with peppery overtones. Volatile oils found in the plant contain eugenol, an antimicrobial agent (Riffle, 1998; Yaniv and Bacharach, 2005).

Anise (*Pimpinella anisum*) also called aniseed is a flowering plant in the family Apiaceae. Anise bears a strong family resemblance to the members of the carrot family that includes dill, fennel, coriander, cumin and caraway. Anise is native to the eastern Mediterranean region, the Levant and Egypt. Anise is a herbaceous annual plant growing to 3 ft (0.91 m) tall. The leaves at the base of the plant are long and shallowly lobed, while leaves higher on the stems are feathery pinnate, divided into numerous leaves. The flowers are white, approximately 3 mm diameter, produced in dense umbels. The fruit is an oblong dry schizocarp, usually called "aniseed". Anise is sweet and very aromatic, distinguished by its characteristic flavour. The seeds, whole or ground, are used in a wide variety of regional and ethnic confectioneries (Albert-Puleo, 1980; Philip, 1999).

Rosemary (*Rosmarinus officinalis*) is a woody, perennial herb with fragrant, evergreen, needle-like leaves and white, pink, purple or blue flowers, native to the Mediterranean region. It is a member of the mint family Lamiaceae. Rosemary is used as a decorative plant in gardens and has many culinary and medical uses. The leaves are used to flavour various foods like stuffings and roast meats. Rosemary is a popular Labiatae herb with a verified potent antioxidant activity. The antioxidant activity of rosemary is mainly related to phenolic diterpenes which are considered effective free radical scavengers (Dorman *et al.*, 2003).

Cinnamon (*Cinnamomum verum*) is a spice obtained from the inner bark of several trees from the genus Cinnamomum that is used in both sweet and savoury foods. It is native only to the island of Sri Lanka but now widely grown in the South East. Cinnamon bark is one of the few spices that can be consumed directly. Its flavour is due to an aromatic essential oil that makes up 0.5% to 1% of its composition. Other chemical components of the essential oil include ethyl cinnamate, eugenol (found mostly in the leaves), beta-caryophyllene, linalool, and methyl chavicol (Wondrak *et al.*, 2010).

Marjoram (*Origanum majorana*) is a cold-sensitive perennial herb or undershrub with sweet pine and citrus flavours. Marjoram is cultivated for its aromatic leaves, either green or dry, for culinary purposes. The tops are cut as the plants begin to flower and are dried slowly in the shade. It is often used in herb combinations. The flowering leaves and tops of marjoram are steam-distilled to produce an essential oil that is yellowish in color (darkening to brown as it ages). It has many chemical components, some of which are borneol, camphor and pinene (Douglas, 2001; GRIN, 2011).

Turmeric (*Curcuma longa*) is a rhizomatous herbaceous perennial plant of the ginger family, Zingiberaceae. It is native to tropical South Asia and needs temperatures between 20 °C and 30 °C and a considerable amount of annual rainfall to thrive. active ingredient is curcumin and it has a distinctly earthy, slightly bitter, slightly hot peppery flavour and a mustardy smell. Turmeric is usually used in its dried, powdered form but it is also used in fresh form much like ginger. It has numerous uses such as fresh turmeric pickle, which contains large chunks of soft turmeric.

Although most usage of turmeric is in the form of root powder, in some regions leaves of turmeric are used to wrap and cook food. This usually takes place in areas where turmeric is grown locally since the leaves used are freshly picked and this imparts a distinct flavour (Gregory *et al.*, 2008; Chan *et al.*, 2009.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

This study was conducted at the Animal Products Laboratory of the Department of Animal Science, Ahmadu Bello University, Zaria. Zaria is located on Latitude 11^0 12' N, Longitude 07^0 33' E at an altitude of 660 m above sea level, along Zaria-Funtua Road in the Northern Guinea Savannah zone of Nigeria (Ovimap, 2018).

3.2 Research Design

This was a 1+3 x 3 factorial arrangement in a Completely Randomized Design (CRD) experiment, which consisted of a control and three spices which were the cloves (*Eugenia aromatica*), ashanti pepper (*Piper guineense*), and negro pepper (*Xylopia aethiopica*), at three inclusion levels (2%, 3%, and 4%). The control had none of the spices of interest included in its spice mix, other than the general condiments used by the local producers. Treatments were sampled at three day periods (one, four and seven days). There were ten replicates per treatment with a total of 40 samples randomly allocated to the 4 treatments. Samples were obtained from these and used for the sensory, chemical and microbial analyses.

3.3 Experimental Materials

The following materials were used:- Beef, skewing sticks (geza), curry, dry pepper, dry clove *seeds*, dryashanti pepper seeds, drynegro pepper seeds, buckets, trays, sieve, groundnut cake, salt, seasoning cubes, groundnut oil, fire-woods, wire mesh, 20kg weighing balance, 2kg sensitive kitchen scale, paper tape, Petri-dishes, foil papers, serviettes, medical hand-gloves, nose mask, micro meter screw guage, and a microwave (for preheating during the sampling days before sensory evaluation).

3.4 Meat preparation

Raw beef of about 15kg obtained from the thigh of a freshly slaughtered matured bull was purchased from the local abattoir in Zango, Zaria. The meat was trimmed free of all visible bones, fats and excess connective tissues. It was then properly washed and after cut in thin sheets ranging from 7.59 -8.78mm in thickness, using a knife with a sharp blade as outlined by Oyadeyi *et al.*(2014). Maximum hygiene was put in place in the processing of the meat.

3.5 Skewering Process

A total of forty skewing sticks (*geza*) were used for the four treatments made up of the 3 different spices included in the spice mix and a control without any of the spices of interest. The meat was properly skewered following the procedures as demonstrated by the local producers, whereby the flesh of the thinly sliced meat was pierced at it's center with the *geza* securing it firmly so it does not fall off during grilling. A skewer had three (3) pieces of meat each.

3.6 Ingredient Preparation

The spices (dry seeds) and other ingredients were locally sourced from the Sabon Gari market in Zaria town. The dry seeds were rinsed with distilled water and left to air dry sufficiently and thereafter ground into powder by use of a pestle and mortar. The ingredients, condiments and others such as groundnut cake (*kulikuli*, 71.7g), common salt (4.1g), dry pepper (6.9g), curry

Levels (g) spices

powder (0.8g), thyme (0.5g), seasoning cube (6.2g), onga seasoning (1.9g) and groundnut oil (7.9ml) were mixed together to prepare the spice mixture for the test ingredients. The treatments (aside from the control) had each of the spices included at the varied inclusion level of 2, 3 and 4% each as seen in Table 3.1.

Table 3.1: *Suya* dried spice mix ingredients incorporated with selected herbs at varied inclusion levels (100%/kg meat)

Ingredients (g)		2.0 ABC	3.0 ABC	4.0 ABC
Groundnut cake	**71.7**	**71.7**	**71.7**	**71.7**
Common salt	**4.1**	**4.1**	**4.1**	**4.1**
Dried pepper	**6.9**	**6.9**	**6.9**	**6.9**
Onga seasoning	**1.9**	**1.9**	**1.9**	**1.9**
Seasoning cube	**6.2**	**6.2**	**6.2**	**6.2**
Thyme	**0.5**	**0.5**	**0.5**	**0.5**
Curry powder	**0.8**	**0.8**	**0.8**	**0.8**
Groundnut oil (ml)	**7.9**	**7.9**	**7.9**	**7.9**

A= Cloves, B= Ashanti pepper, C= Negro pepper

3.7 Preparation of *Suya*

The weight of theskewingsticks were taken and recorded, after which the meat was skewered on the slender wooden sticks. The average weight of the sticks and meat was likewise taken and recorded in addition to the weight of the skewered meat having been coated with spice mixture(consisting of the various spices accordingly) of approximately 5g each, and then appropriately labeled. The weighed skewered meat were randomly allotted to 4 treatments consisting of the 3 different spices(cloves, ashanti pepper and negro pepper) and a control (without herbs). The labeled sticks of meat were then lightly sprinkled with groundnut oil of about 5- 10ml each, and then placed on a grill on a glowing, smokeless fire made from charcoals. The distance of the sticks from the fire source taken with a tape rule was 25cm. The skewers were allowed to stay on the fire for 20 minutes with regular turning of the product, intermittently additional groundnut oil of about 2ml was sprinkled on each of the meat while roasting continued. The preparation was done following methods outlined by Bube (2003) as seen in Fig 3.1.

After cooking and allowing to cool for about 20 minutes, the length (determined using a measuring tape), weight (determined using a sensitive scale) and thickness (determined using a micro meter screw guage) of each *suya*was determined and this was then used in calculating the thermal shortening, percentage cooking loss and the product yield according to procedures outlined by Oyadeyi *et al.*(2014). Samples for the determination of the physico-chemical and microbial analysis of the*suya* were also taken to the laboratory for analysis. The samples used for the analysis were assayed in duplicates.

Cleaned Fresh meat

↓

Slicing into thin sheets

↓

Skewering/sticking the sliced meats

↓

Coating of meat with spice mixtures having different spice inclusion

↓

Placing on the grill

↓

Grilling

↓

Suya

Fig. 3.1: A flow diagram showing the process of *Suya*preparation.

Source: Bube (2003)

3.8 Proximate analysis

The suya meat (50g) was taken for chemical analysis on day one, four and seven. About 5g of The ground spices of interest and 100g of raw meat samples were also analyzed. The variables analyzed were moisture, dry matter, crude protein, ether extract and ash using the procedures described by AOAC (2005). The proximate analysis was carried out at the Biochemistry Laboratory of the Department of Animal Science, Ahmadu Bello University Zaria.

3.9 pH measurements

Potentiometric measurements of pH were made with a pin electrode of a pH meter (HANNA pH HI 9813-5, Romania, Europe) inserted directly into the sample. Three independent measurements were made on each sample.

3. 10 Determination of Percentage Cooking Loss

Percentage cooking loss was determined by evaluating the differences in weight of initial sample from cooked divided by the weight before cooking multiplied by 100.

$$\% \text{ cooking loss} = \frac{\text{Initial sample weight} - \text{Cooked sample weight}}{\text{Initial sample weight}} \times 100$$

3.11 Thermal shortening

Thermal shortening was determined by subjecting meat samples of known length and thickness to grilling. The lengths of meat samples were re-measured after grilling for 20 minutes and equilibrating to room temperature. The difference in lengths was expressed as thermal shortening following the modified method of Mahendrakar *et al.* (1988).

Thus: $$\% \text{ Thermal shortening} = \frac{\text{Initial length of meat} - \text{Final length of meat}}{\text{Initial length of meat}} \times 100$$

3.12 Product yield

The product yield of meat floss was calculated using the method described by Kembi and Okubanjo (2002). It was expressed as the ratio of the final weight of the product (*suya*) to the initial fresh meat samples.

$$\text{Product Yield (\%)} = \frac{\text{Weight of } suya}{\text{Weight of raw meat samples}} \times 100$$

3.13 Sensory evaluation

Sensory evaluation was carried out on bite sizes averaging about 2g of each *suya* sample served on labeled plates by 30 semi-trained panelists who were familiar with the taste of *suya* over the storage period of one, four and seven days. Colour, texture, tenderness, juiciness, aroma and overall acceptability were analyzed. Clean water, toothpicks, handwash and serviette paper were provided to the entire panelists prior to the evaluation process. A cup of clean water (for rinsing the mouth) and cracker biscuits (for effective erasing of the presence of a previously tasted sample) was also provided for each panel member on each evaluation day. The samples evaluated on days 4 and 7 were microwaved for 3mins at medium heat before being served. Organoleptic assessment on each day was done using a 9-point hedonic scale questionnaire given to each panelist to record their perception and observation, with 9 for like-extremely, down to 1 for dislike-extremely (Carbonell *et al.*, 2002**)**. The samples were labeled with codes only known to the researcher and served in a small saucers to the panelist in a good sanitary environment.

3.14 Microbiological Analyses

The microbial analysis of freshly made (day 1), stored for 4 and 7 days *suya* samples was carried out to determine Coliform counts (CF), Staphylococcal counts (SC), Fungal counts (FC) and Aerobic Plate Counts (APC) following the International Commission of Microbiology Specification for foods as outlined by AOAC (2005). The analysis was carried out at the

Microbiology Laboratory, National Research Institute for Chemical Technology Zaria. The recommended methods by the International Commission of Microbiology Specification for foods were:-

3.14.1 Microbial Count

Microbial count of the processed meat (*suya*) samples was performed according to the pour plate method as described by Stuart, (2005). The count was expressed as colony forming unit per gram (cfu/g) for bacterial and spore forming unit per gram (sfu/g) for mold. Microbial load guide in animal food product, according to Wilson and Sperber (1991) is shown in Table 3.2.

3.14.2 Biochemical test procedure for characterization and identification of bacteria

3.14.2.1 Morphological characterization (Gram staining reaction)

The Gram staining reaction method of McKane and Kandel (1996) was used to identify isolates based on their Gram reaction (Gram positive or Gram negative) and morphology (shape).

3.14.2.2 Durham tube sugar fermentations of glucose, lactose, sucrose

Prescott *et al.* (2002) method for fermentation test was carried out in other to distinguish isolates that can ferment carbohydrate or not.

3.14.2.3 Indole test: Tryptophan hydrolysis

Indole test using Cheesbrough. (2000) method was carried out to detect production of tryptophanase by the bacteria isolates.

Table 3.2 Standard Microbial Load Specification On Animal Food Product.

GRADES	TVBC (total viable bacterial count)	Coliform count	Description
I	$<10^4$ million	$<10^2$ million	Satisfactory
II	$<10^4$ - $<10^6$ milllion	$<10^2$ - $< 10^4$ million	Acceptable
III	$>10^6$ million	$>10^4$ million	Unsatisfactory

Source: Wilson and Sperber (1991).

3.14.2.4 Methyl red test

Methyl red test using Cheesbrough. (2000) methodwas conducted to determine mixed acid fermentation (lactic, acetic, formic) as part of the IMViC (Indole, Methyl Red, Voges Proskauer, Citrate) test.

3.14.2.5 Voges proskauer test

Voges Proskauer test using Cheesbrough. (2000) method was conducted to detect the production of acetoin (acetylmethyl carbinol) or 2,3 butainediol (acetoin is the precursor) from glucose broth by the bacteria isolates. It is also part of the IMViC test.

3.14.2.6 Simmon's citrate test

Simmon's citrate using Prescott *et al.* (2002) method was carried out to determine a bacteria's ability to use citrate as the sole source of carbon. Part of the IMVIC test series (Indole, Methyl Red, Voges-Proskauer, Citrate).

3.14.2.7 Catalase test

Catalase testusing Cheesbrough. (2000) method was carried out in order to detect the production of catalase by the bacteria isolates.

3.14.2.8 Oxidase test

Oxidase test using Prescott *et al.* (2002) method was conducted in order to identify organisms that produce the enzyme cytochrome oxidase.

3.14.2.9 Urease test

Urease test using Cheesbrough. (2000) method was used to detect the production of the enzymes urease by the bacteria pathogens.

3.14.2.10 Triple sugar iron agar test

Triple sugar iron agar test using Stuart (2005) method was used to differentiate the bacteria isolates by their ability to ferment glucose, lactose, and sucrose, and produce gas and/or hydrogen sulfide.

3.14.2.11 Coagulase test

Coagulase test using Stuart (2005) method was conducted to detect the ability of the bacteria isolates to cause plasma to clot by converting fibrinogen to fibrin. Using a sterilized wire loop, a bacteria smear was made on a clean glass slide.

3.15 Sample storage

Prior to subsequent analysis on days four and seven, the *suya*samples were kept at room temperature (27.6 to 31.7^{0}C) and a surface temperature range of 24.6 to 32.0^0 C, over the storage period, on a wooden platform spread with newspaper and covered all around with mosquito netting for proper aeration and insect proofing specially constructed for this purpose (Fig 3.2). It was wrapped in aluminum foil on days four and seven that it was taken out for microbial, proximate and sensory analysis.

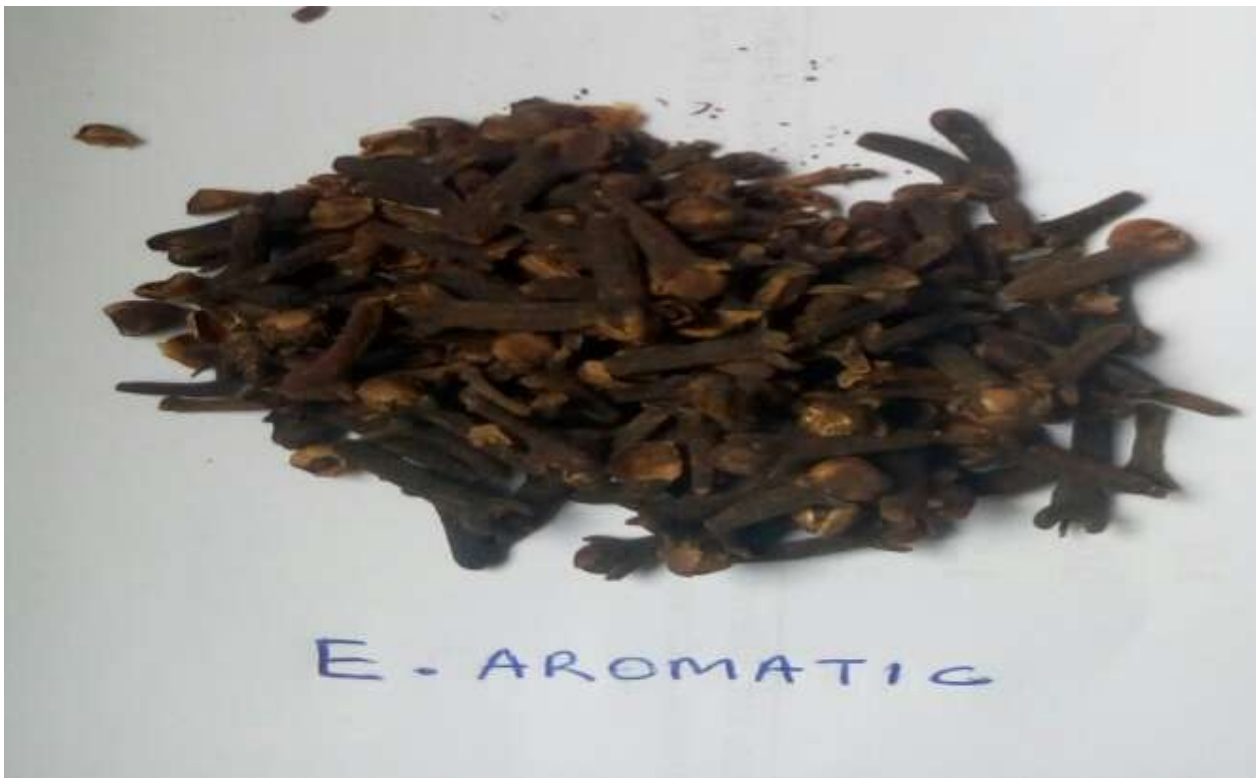

Fig 3.2 Shows an imagery of the Cloves (*Eugenia aromatica*) spice.

Fig 3.3 Shows an imagery of the Ashanti pepper (*Piper guineense*) spice.

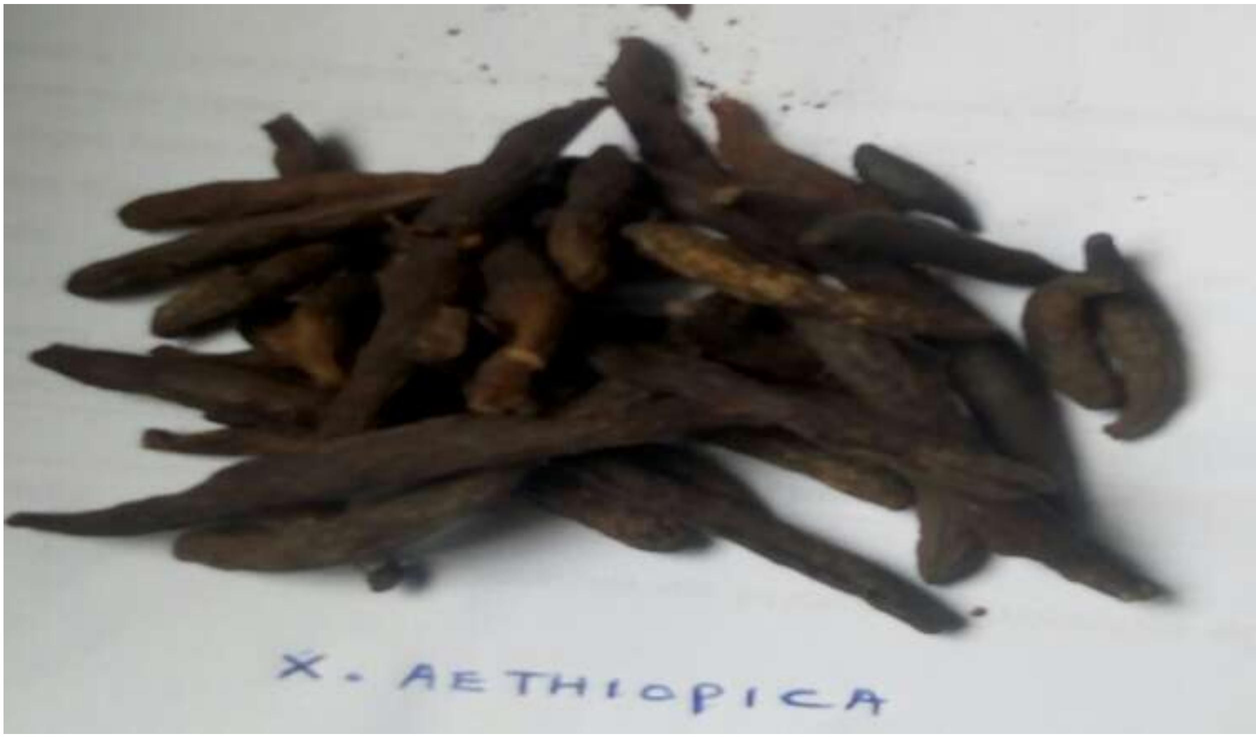

Fig 3.4 Shows an imagery of the Negro pepper (***Xylopia aethiopica*****) spice.**

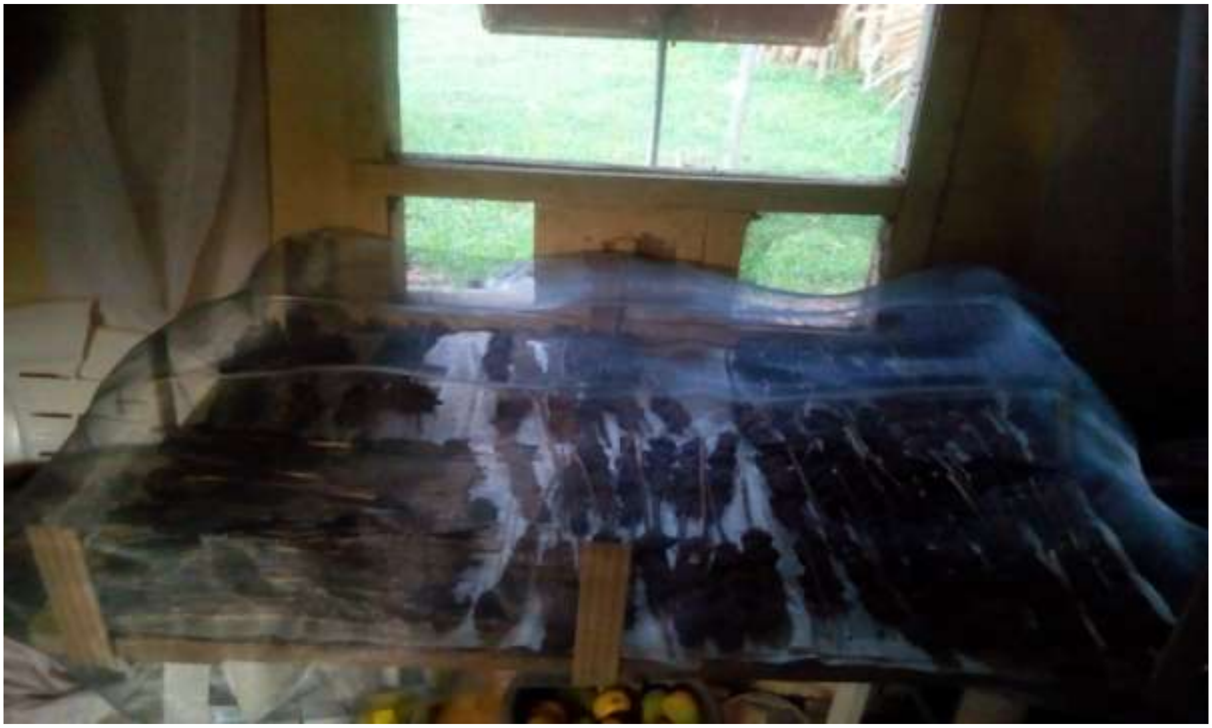

Fig 3.5 Shows the *suya* being stored at room temperature after preparation on day one in a net enclosed space.

3.16 Statistical Analysis

The data collected from the experiment in triplicates, were subjected to Analysis of Variance (ANOVA) using the general linear model procedure of SAS (2008) while the means comparison was done using Dunnett (1955).

Microbial means were transformed using log transformation before analysis. The formulae for this transformation is below:

SQRT: $Y' = \sqrt{(Y+0.5)}$

Y=Original data to be transformed.

0.5= A constant.

Y'= Transformed data (Steel and Torrie, 1960)

Model used: $Y_{ijk} = \mu + T_i + L_J + (T \times L)_{ij} + e_{ijk}$

Where:-

Y_{ijk} = Dependent variable

μ= Overall mean

T_i=Fixed effect of the i^{th} treatment (Ashanti pepper, *Negro pepperand* Clovesand control)

L_j= Effect of the j^{th} inclusion level (2%, 3% and 4%)

$T \times L_{(ij)}$= The effect of interaction of i^{th} treatment and j^{th} inclusion level

ε_{ijk}= Residual error, which is assumed to be identically independent and normally distributed with zero mean and constant variance (iind, $0\sigma^2$).

CHAPTER FOUR

4.0. RESULTS

4.1. Proximate composition of the test ingredients

Table 4.1 shows the proximate composition of the fresh seeds of the cloves, ashanti pepper and negro pepperused in the *suya*spice mix.

Dry matter content was lowest in the ashanti pepper having a value of 87.11%, this was followed by that of cloves having a value of 92.75% and the highest was that of Negro pepper with 93.47%. Mineral content was more in ashanti pepper at 8.0%, followed by that of cloves, 5.31% and the least was negro pepper, 4.64%. Crude protein content was higher in the cloves spice having a value of 21.73%, and was followed by that of the negro pepper spice which had a value of 20.82% and the least which was the ashanti pepper having 15.50%. Crude fibre was more in ashanti pepper at 11.15%, followed by that in cloves, 7.45% and least was in negro pepper at 6.73%. negro pepper had an ether extract content of 34.70% while cloveshad a content of 29.80% and the least ashanti pepper having an ether extract content of 18.2%.

4.2Proximate composition of fresh beef

Table 4.2 shows the proximate composition of the fresh beef prior to its being processed into *Suya*. Dry matter content was 27.28%, moisture content was 72.74, crude protein content was 18.22%, ether extract was 6.58%, NFE was 1.13% and Ph was 6.8.

4.3 Microbial analysis of fresh beef

The result of Microbial analysis of fresh beefis shown in Table 4.3. This result shows the values total viable bacteria count was 4.3×10^4, total coliform count was 2.9×10^2, while for total yeast and mould counts, no count was detected.

Table 4.1: Proximate Composition of dried seeds of cloves(*Eugenia aromatica*), ashanti pepper (*Piper guineense*),*and*negro pepper (*Xylopia aethiopica*)

Parameters (%)	Cloves	Ashanti pepper	Negro pepper
Dry Matter	92.75	87.11	93.47
Moisture content	7.25	12.89	6.53
Nitrogen-free extract	28.46	34.26	26.58
Crude protein	21.73	15.50	20.82
Crude fiber	7.45	11.15	6.73
Ether extract	29.80	18.20	34.70
Ash	5.31	8.00	4.64

Table 4.2: Chemical composition (%) of raw/ fresh beef

Parameters (%)	Raw Beef
Dry Matter	27.28
Moisture content	72.74
Ash	1.33
Crude protein	18.22
Ether extract	6.58
Nitrogen-free extract	1.13
Ph	6.8

Table 4.3: Microbial analysis of raw/fresh beef

Parameters	Cfu/g
Total viable bacteria count	4.3×10^4
Coliform count	2.9×10^2
Total yeast count	ND
Total mould count	ND

Cfu/g= Colony Forming Unit per gram, ND= Not Detected

4.4 Physical changes in the final product (*Suya*) from the initial product

In Table 4.4, the effect of the physical changes in the *suya* from that of the initial product is seen. Weight of the skewing sticks (*geza*) was 5.0g. The average weight of the thinly sliced fresh meat prior to it being coated with spices, when weighed using a 2kg sensitive scale was 6.16g, however on coating with all four treatments, average weight taken ranged between 11.33- 12.47g. After the coated meat was grilled, average weight was 10.16g. Length of the *suya*prior to grilling on an average was 6.0cm and after grilling was 5.3cm. Thickness of the *suya*before grilling was 10.20, after grilling this reduced to 8.70mm.

Average cooking loss when calculated was 10.33%. Average thermal shortening was 11.67%. Average product yield was 89.67%.

4.5: Effect of treatments and varied levels of inclusion on the Physico-chemical composition of *suya* on sampling day one

Table 4.5 shows the mean values of the effect of the different spices (Ashanti pepper, Negro pepper and Cloves), different inclusion levels (2, 3 and 4%) and subsequent interaction (treatment and levels) on the proximate composition of the *suya*on day one. It was observed that the moisture content, ash content, ether extract content, crude protein content, pH and TBARS values were numerically and statistically different.

The moisture content of *suya*containingAshanti pepper (SCA)was more ($P<0.05$) with a value of 68.05 than the other treatments, in which*suya*containing cloves (SCC) followed with a value of 67.52, while *suya* containing Negro pepper (SCN) was 67.00 and the least was that of the control (*suya* containing none of the spices of interest) which had a value of 66.27.

Table 4.4: Physical Changes in the initial readings from the final product (*Suya*)

PARAMETERS	INITIAL READINGS	FINAL PRODUCT
Average weight of the raw spiced meat(g)	6.16	11.33
Average weight of *Suya*(g)	11.33	10.16
Average thickness of *Suya*(mm)	8.78	7.59
Average length of *Suya*	6.00	5.30
pH	6.80	6.20
Average cooking loss (%)		10.33
Average thermal shortening (%)		11.67
Average product yield (%)		89.67
Weight of skewing sticks(g)		5.00

Table 4.5: Effect of treatments and varied levels of inclusion on the Physico-chemical composition of *suya*on sampling day one

Treatment	M.C	ASH	E.E	C.P	NFE	pH	TBA
Treatments							
SCC	67.52^{b}	1.57^{b}	5.88^{c}	20.88^{b}	2.94^{b}	6.1^{b}	0.03^{b}
SCA	68.05^{a}	1.50^{b}	5.77^{c}	20.53^{bc}	2.99^{b}	6.4^{a}	0.03^{b}
SCN	67.00^{bc}	1.91^{a}	6.65^{b}	20.23^{c}	3.24^{a}	5.9^{c}	0.04^{a}
Control	66.27^{c}	1.50^{b}	8.23^{a}	22.43^{a}	1.52^{c}	5.8^{d}	0.02^{c}
SEM	0.271	0.068	0.184	0.246	0.120	0	0
Inclusion (%)							
2	68.55^{a}	1.47^{b}	5.09^{c}	20.58	3.11^{b}	6.13^{b}	0.03
3	67.52^{b}	1.36^{b}	6.37^{b}	20.26	3.42^{a}	6.20^{a}	0.03
4	66.34^{c}	2.15^{a}	6.84^{a}	20.80	2.64^{c}	6.03^{c}	0.03
SEM	0.271	0.068	0.184	0.246	0.120	0	0
Interaction							
Spices*Inclusion	**	**	**	**	**	**	**

^{abcd} means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen, TBA= Thiobarbituric acid.

The ash content of SCN was more (P<0.05) than those treated with SCC, SCAand the control which were observed to be similar with values which ranged between 1.50-1.91%. The ether extract of the control samples were higher (P<0.05) than those treated with spices, having value ranges of between 5.77-8.23%. SCC and SCA were however statistically similar. For crude protein, the control, was higher (P<0.05) than those treated with spices, having values which ranged between 20.23- 22.43%. NFE showed SCNbeing higher (P<0.05) with a value of 3.24 and the least was the control with a value of 1.52. The pH values showed SCAto have been higher (P<0.05) with a pH of 6.4 followed by that prepared with SCC(6.1), SCN(5.9)and least was the control (5.8). TBARS value was higher (P<0.05) in SCNand least in the control, however SCCand SCAwere similar.

At varied inclusion level, 2% inclusion was the highest with a value of 68.55, followed by that of 3% with a value of 67.52, and the least being that of 4% having a value of 66.34. Ash content was higher (P<0.05) in 4% inclusion level than in inclusion levels of 3% and 2% which were the same. Ether extract content was also higher (P<0.05) at 4% level of inclusion than in those of 3% and 2%, having values of 6.84%, 6.37% and 5.09% respectively. The crude protein content of the *suya* marinated at the three levels of inclusion (2, 3 and 4%), although numerically different, showed no statistical (P<0.05) difference. The NFE values were higher (P<0.05) at 3% inclusion level than the other means. Values for pH was higher (P<0.05) at 3% (6.2) inclusion level, followed by that at 2% (6.1) and least was that included at 4% (6.0). The TBARS content of the *suya* marinated at the three levels of inclusion (2, 3 and 4%), were numerically alike and showed no statistical (P<0.05) difference. Interaction effect between the spices and their varied inclusion levels showed high significant (P<0.05) differences across all the physico-chemical parameters.

4.6: Effects of treatment and varied inclusion levels on the Physico-chemical composition of *suya* at day four sampling period

Table 4.6 shows the mean values of the effect of the treatments (control, SCA, SCNandSCC), varied inclusion levels (2, 3 and 4%) and their interactions (treatment and levels) on the physico-chemical properties of the *suya* on day four sampling period. It was observed in Table 4.6, that the moisture content, ash content, ether extract content, crude protein content, pH and TBARS values were different.

The moisture content of *suya* treated with SCCwas significantly (P<0.05) more (63.71%), than that treated with SCA (63.01%), SCN (61.79) and the control (61.59). The ash content of *suya* that was the controlwas higher (P<0.05) at 2.07% than those treated with SCC, and SCN which were observed to be similar (1.85%) and SCA (1.64%).

The ether extract of the control samples were also higher (P<0.05) than those treated with spices, having value ranges of between 6.19-7.39%. For crude protein, the *suya* which was the control, had higher (P<0.05) values than those treated with spices, having values which ranged between 20.19- 22.07%. NFE values was statistically higher in SCNhaving a value of 9.09while SCCand the control were the least significant with respective values of 6.56 and 6.46. The pH values showed SCNto have been higher (P<0.05) with a pH of 6.3 followed by SCA(6.2), SCC(5.9)and least was the control (5.8). TBARS value was alike (P>0.05) in SCN, SCCand SCAand was different (P<0.05) in the control. At varied inclusion levels, moisture content was significantly (P<0.05) higher in 2 and 4% (63.35 and 63.83%) level of inclusion than that included at 3%

(61.33%). Ash content was higher (P<0.05) in 4% inclusion level than in inclusion levels of 3% and 2% which were similar.

Table 4.6: Effects of treatment and varied inclusion levels on the Physico-chemical composition of *suya* at day four sampling period

Treatments	M.C	ASH	E.E	C.P	NFE	pH	TBA
Spices							
SCC	63.71 [a]	1.85 [ab]	6.19 [c]	20.56 [b]	6.56 [c]	5.9 [c]	0.22 [a]
SCA	63.01 [b]	1.64 [b]	6.50 [b]	20.25 [b]	7.54 [b]	6.2 [b]	0.24 [a]
SCN	61.79 [c]	1.85 [ab]	6.21 [c]	20.19 [b]	9.09 [a]	6.3 [a]	0.23 [a]
Control	61.59 [c]	2.07 [a]	7.39 [a]	22.07 [a]	6.46 [c]	5.8 [d]	0.12 [b]
SEM	0.263	0.159	0.129	0.315	0.291	-	0.011
Inclusion (%)							
2	63.35 [a]	1.69 [b]	6.05 [c]	20.54	7.47 [b]	6.18 [a]	0.24 [a]
3	61.33 [b]	1.69 [b]	6.37 [b]	20.02	9.64 [a]	6.16 [b]	0.20 [b]
4	63.83 [a]	1.96 [a]	6.48 [a]	20.43	6.09 [c]	6.09 [c]	0.25 [a]
SEM	0.263	0.159	0.129	0.315	0.291	-	0.011
Interaction							
Spices*Inclusion	**	NS	NS	**	**	**	**

[abcd] means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen,TBA= Thiobarbituric Acid, NS=Not significant

Ether extract content was also higher (P<0.05) for 4% level of inclusion than those of 3% and 2%, having values of 6.48%, 6.37% and 6.05% respectively.The crude protein content of the *suya* marinated at the three levels of inclusion (2, 3 and 4%), was not different (P<0.05). NFE values was statistically higher in that marinated at 3% inclusion level having a value of 9.64 and the least was in the 4% inclusion level with a value of 6.09. Values for pH decreased at increased levels of inclusion having values of 6.18, 6.16 and 6.09 at 2%, 3% and 4% respectively. The TBARS content of the *suya* marinated at 4% inclusion level was higher (P<0.05) than that of 2% and 3%, and had values of 0.25, 0.24 and 0.20mg/100g respectively.

Interaction effect between the spices and their varied inclusion levels showed significant (P<0.05) differences in moisture content, crude protein content, pH and TBARS content of the *suya*, however ash content and ether extract content were not significant (P>0.05).

4.7: Effect of treatment, varied inclusion levels and their interaction on the Physico-chemical properties of *suya* on day seven sampling period

The mean values of the effect of the treatments (control, SCA, SCN andSCC), varied inclusion levels (2, 3 and 4%) and their interactions (treatment and levels) on the physico-chemical properties of the *suya* on day seven sampling period as seen in Table 4.7 shows that the moisture content, ash content, ether extract content, crude protein content, pH and TBARS values were numerically and statistically different. The moisture content of SCC was significantly (P<0.05) more (59.75%) than SCN(56.22%), SCA(54.00%) and the control (53.06%). The ash content of the controlwas significantly (P<0.05) more (2.44%) than SCC (2.26%), SCN (2.17%) and SCA (1.65%).

The ether extract of the *suya* treated with SCAwas higher (P<0.05) than that of the control (6.69), however that treated with *SCN*and SCCwere alike (P>0.05) having values of 6.43% and 6.31% respectively.

Table 4.7: Effect of treatment, varied levels of inclusion and their interaction on the Physico-chemical properties of *suya* on day seven sampling period

Treatments	M.C	ASH	E.E	C.P	NFE	pH	TBA
Spices							
SCC	59.75^{a}	2.26^{ab}	6.31^{c}	20.19^{c}	10.40^{d}	5.9^{a}	0.94^{d}
SCA	54.00^{c}	1.65^{c}	7.63^{a}	20.63^{b}	15.13^{a}	5.5^{c}	0.95^{c}
SCN	56.22^{b}	2.17^{b}	6.43^{c}	19.84^{c}	14.51^{c}	5.9^{a}	0.98^{a}
Control	53.06^{d}	2.44^{a}	6.69^{b}	22.36^{a}	14.81^{b}	5.8^{b}	1.17^{a}
SEM	0.193	0.103	0.112	0.181	0.121	-	-
Inclusion (%)							
2	54.51^{c}	2.11^{a}	6.93^{a}	20.17^{b}	15.46^{a}	5.3^{c}	1.00^{a}
3	56.62^{b}	2.09^{a}	7.05^{a}	19.65^{c}	13.54^{b}	5.7^{b}	0.98^{b}
4	58.84^{a}	1.89^{b}	6.39^{b}	20.85^{a}	11.04^{c}	6.3^{a}	0.89^{c}
SEM	0.193	0.103	0.112	0.181	0.121	-	-
Interaction							
Spices*Inclusion	**	**	**	**	**	**	**

^{abcd} means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen, TBA= Thiobarbituric Acid.

For crude protein, the control, had higher (P<0.05) values than those treated with spices, having values which ranged between 19.84- 22.36%. NFE values ranged between 10.40-15.13%, with SCC being the least and SCA being the highest. The pH values showed SCNand SCCto have been alike (P<0.05) having pH values of 5.9, followed closely by the control(5.8), with the least being SCA (5.5). TBA values in the controlwas higher (P>0.05) at 1.17 mg/100g, than those of SCN, SCAand SCC, (0.98, 0.95 and 0.94 mg/100 respectively).

At varied inclusion levels, moisture content was statistically (P<0.05) higher in 4% (58.84%) level of inclusion than those included at 3% (56.62%) and 2% (54.51%) respectively. Ash content was higher (P<0.05) in 2% inclusion level than in *suya* with inclusion levels of 3% and 4% whose values were 2.11, 2.09 and 1.89% respectively. Ether extract content was higher (P<0.05) in 3% level of inclusion than in those of 2% and 4%, having values of 7.05, 6.93 and 6.39% respectively.

The crude protein content of the *suya* was significantly (P<0.05) higher in that at 4% (20.85%), followed by that of 2% (20.17%) and the least was 3% (19.65%). Values for pH showed higher (P<0.05) values in that of 4% (6.3) than those of 3% and 2% (5.7 and 5.3 respectively). NFE values steadily decreased as the levels of inclusion increased, with values which ranged from 11.04-15.46.

The TBA value of the *suya* marinated at 2% inclusion level was statistically (P<0.05) higher (1.00 mg/100g) than that of 3% and 4% (0.98 and 0.89 mg/100g respectively).

Interaction effect between the spices and their varied inclusion levels showed high significant (P<0.05) differences among all the physico-chemical parameters.

4.8: Interaction effect between treatments and varied levels of inclusion on the Physico-chemical properties of *suya* on day one sampling period

Table 4.8 shows the mean values of the effect of the interactions between treatment and levels on the physico-chemical properties of the *suya* on day one sampling period. It was observed that the moisture content, ash content, ether extract content, crude protein content, pH and TBA values were significantly (P<0.05) different.

The moisture content of *suya* treated with SCAat 2% inclusion level was significantly more (69.61%) than SCA at 3% inclusion level (69.01%), SCCat (68.62%),SCNat 2% inclusion level(67.41%), SCNat 3% inclusion level (67.09%), SCC at 4% inclusion level (67.00%), SCNat 4% inclusion level (66.50%), control (66.27%) and the least significant was SCAat 4% inclusion level (65.52%).The ash content of *suya* treated with SCCat 4% inclusion level, was higher (P<0.05) with a value of 2.34% than the rest, which in descending order had values of 2.09% (SCN at 4%), 2.03% (SCA at 4%), 1.94% (SCN at 2%), 1.70% (SCNat 3%), 1.50% (control), 1.27% (SCC at 2 % and SCA at 3%), 1.20% (SCAat 2%) and 1.10% (SCC at 3%).

The ether extract of the control samples was higher (P<0.05) with a value of 8.23% than those treated with spices, having values of 7.70% (SCN at 4%), 6.99% (SCC at 4%), 6.90% (SCC at 3%), 6.63% (SCN at 2%), 6.59% (SCA at 3%), 5.82% (SCA at 4%), 5.61% (SCN at 3%), 4.89% (SCA at 2%) and 3.76% (SCC at 2%). For crude protein, the control and that treated with SCC had higher (P<0.05) values of 22.43% and 22.38% respectively than the rest which had values of 21.03% (SCAat 4%), 20.98% (SCN at 4%), 20.82% (SCN at 3%), 20.46% (SCA at 2%), 20.39% (SCC at 4%), 20.00% (SCA at 3%), 19.88% (SCC at 3%), and least was 18.89% (SCN at 2%).

Table 4.8:Interaction effects between treatments and varied levels of inclusion on the Physico-chemical properties of *suya* on day one sampling period

Treatment	Level	M.C	Ash	E.E	NFE	C.P	pH	TBA
SCC	**2.0**	68.62^{b}	1.27^{e}	3.76^{f}	2.69^{c}	22.38^{a}	6.3^{b}	0.02^{c}
	3.0	66.94^{c}	1.10^{e}	6.90^{c}	4.41^{b}	19.88^{bc}	6.0^{d}	0.03^{b}
	4.0	67.00^{c}	2.34^{a}	6.99^{c}	1.71^{d}	20.39^{bc}	5.9^{e}	0.03^{b}
SCA	**2.0**	69.61^{a}	1.20^{e}	4.89^{e}	2.46^{c}	20.46^{bc}	6.3^{b}	0.04^{a}
	3.0	69.01^{b}	1.27^{e}	6.59^{c}	1.81^{d}	20.00^{bc}	6.4^{a}	0.03^{b}
	4.0	65.52^{d}	2.03^{b}	5.82^{d}	4.70^{a}	21.03^{b}	6.4^{a}	0.03^{b}
SCN	**2.0**	67.41^{c}	1.94^{b}	6.63^{c}	4.18^{b}	18.89^{c}	5.8^{f}	0.03^{b}
	3.0	67.09^{c}	1.70^{c}	5.61^{d}	4.04^{bc}	20.82^{b}	6.2^{c}	0.04^{a}
	4.0	66.50^{cd}	2.09^{b}	7.70^{b}	1.50^{d}	20.98^{b}	5.8^{f}	0.04^{a}
Control	**__**	66.27^{cd}	1.50^{d}	8.23^{a}	1.52^{d}	22.43^{a}	5.8^{f}	0.02^{c}
SEM		0.267	0.068	0.184	0.120	0.246	_	_

abcdef means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen,TBA= Thiobarbituric Acid.

For NFE, values ranged between 1.50– 4.70% with the least value being SCN at 4% and the highest value being SCA at 4% inclusion level. The pH values showedSCA at 3% and 4%to have been higher (P<0.05) with a pH of 6.4 followed by SCAand SCC at 2%(6.3), SCNat 3%(6.2), SCC at 3% (6.0), SCC at 4% (5.9),and least was the control and SCN at 2 and 3% (5.8). TBA value was not significantly (P>0.05) different from SCNat 3 and 4% and SCA at 2% (0.04 mg/100g), followed by SCN at 2%,SCCat 3% and 4%, SCAat 3% and 4% which was also not different (P>0.05) at 0.03 mg/100g, and the least (0.02 mg/100g) were the control and SCC at 2%.

4.9: Interaction effect between treatments and varied levels of inclusion on the Physico-chemical properties of *suya* on day four sampling period

Table 4.9 shows the mean values of the effect of the interactions between treatment and levels on the physico-chemical properties of the *suya* on day four sampling period. It was observed that the moisture content, crude protein content, pH and TBA values were numerically and statistically different. However, ash content and ether extract content were not statistically different (P>0.05).

The moisture content of SCC at 4% and SCA at 4% level of inclusion had statistically (P<0.05) higher values than the rest and was followed by SCC at 2%, SCN at 2% and SCA at 2% which were statistically (P<0.05) similar with values of 63.54, 63.49 and 63.01% respectively, SCN at 4% (62.29%) was next and this was followed by the control (61.59%) and SCA at 3% (61.50%), which were both statistically similar, the least was SCN at 3% inclusion level which had a value of 59.58%.

For crude protein, the control had higher (P<0.05) values of 22.07% than the rest.SCN at 4%, SCC at 2% and 4%, and SCA at 2 and 3%, were all similar with values of 21.10, 21.07, 21.02 , 20.86 20.72% respectively, while SCN at 2 and 3%, SCC at 3% and SCA at 4% were the least and were also not significant (P>0.05) having values of 19.69, 19.75, 19.59 and 19.17% respectively.

Table 4.9: Interaction effect between treatments and varied levels of inclusion on the Physico-chemical properties of *suya* on day four sampling period

Treatment	Level	M.C	Ash	E.E	C.P	NFE	pH	TBA
SCC	2.0	63.54^{b}	1.76	5.99	21.07^{b}	6.77^{d}	6.0^{c}	0.19^{d}
	3.0	62.92^{b}	1.83	6.17	19.59^{c}	8.45^{b}	5.9^{e}	0.22^{c}
	4.0	64.67^{a}	1.95	6.40	21.02^{b}	4.46^{e}	5.9^{e}	0.19^{d}
SCA	2.0	63.01^{b}	1.57	6.05	20.86^{b}	7.39^{c}	6.3^{b}	0.23^{b}
	3.0	61.50^{d}	1.48	6.60	20.72^{b}	8.79^{b}	6.3^{b}	0.25^{b}
	4.0	64.53^{a}	1.88	6.84	19.17^{c}	6.46^{d}	6.0^{c}	0.23^{b}
SCN	2.0	63.49^{b}	1.74	6.10	19.69^{c}	8.24^{b}	6.3^{b}	0.23^{b}
	3.0	59.58^{e}	1.77	6.32	19.75^{c}	11.67^{a}	6.2^{d}	0.14^{e}

	4.0	62.29 ^{c}	2.05	6.20	21.10 ^{b}	7.35 ^{c}	6.4 ^{a}	0.32 ^{a}
Control	_	61.59 ^{d}	2.07	7.39	22.07 ^{a}	6. 46 ^{d}	5.9 ^{e}	0.12 ^{e}
SEM		0.263	0.159	0.129	0.315	0.291	_	0.011

^{abcde} means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen,TBA= Thiobarbituric Acid.

For NFE, values ranged between 4.46– 11.67% with the least value beingSCC at 4% and the highest value being SCN at 3% inclusion level. The pH values showed SCN at 4% to have been higher (P<0.05) with a pH of 6.4 followed by SCNat 2%, and SCA at 2 and 3% (6.3), SCNat 3%(6.2), SCC at 2% and SCA at 4% (6.0), and least were the control and SCC at 3 and 4% (5.9). TBA value was higher (P>0.05) in SCN 4% (0.32mg/100g), followed by SCN at 2%,SCAat 2, 3 and 4% which were not significantly different (P>0.05) from one another (0.23, 0.23, 0.25 and 0.23mg/100g respectively), SCCat 3% (0.22mg/100g), also SCC at 2 and 4% which had same values (0.19mg/100g) and were not significantly different (P>0.05), and the least significant were the control and SCN at 3% which were both similar and had values of 0.12 and 0.14mg/100g respectively.

4.10: Interaction effect between treatments and varied levels of inclusion on the Physico-chemical properties of *suya* on day seven sampling period

Table 4.10 shows the mean values of the effect of the interactions between treatment and levels on the physico-chemical properties of the *suya* on day seven sampling period. It was observed that the moisture content, ash content, ether extract content, crude protein content, pH and TBA values were numerically and statistically different.

The moisture content of SCC at 4% level of inclusion was (63.34%) higher (P<0.05) than the rest. This was followed by SCC at 3% (59.14%), SCN at 4% (57.65), SCN at 3% and SCC at 2% which were statistically (P<0.05) similar with values of 56.99 and 56.77% respectively, SCA at 4% (55.51%) was next and this was followed by SCN (53.99%), SCA at 3% (53.72%) and the control (53.06%), which were not different (P>0.05), and the least was SCA at 2% inclusion level which had a value of 52.87%.

Table 4.10: Interaction effect between treatments and varied inclusion levels on the Physico-chemical properties of *suya* on day seven sampling period

Treatment	Level	M.C	Ash	E.E	C.P	NFE	pH	TBA
SCC	**2.0**	56.77 ^{d}	2.54 ^{a}	6.35 ^{d}	20.69 ^{d}	12.61 ^{f}	5.3 ^{i}	1.00 ^{c}
	3.0	59.14 ^{b}	2.50 ^{a}	6.64 ^{c}	18.62 ^{g}	11.99 ^{g}	6.0 ^{d}	0.95 ^{d}
	4.0	63.34 ^{a}	1.74 ^{bc}	5.93 ^{e}	21.26 ^{c}	6.60 ^{h}	6.4 ^{a}	0.88 ^{e}
SCA	**2.0**	52.87 ^{g}	1.63 ^{bc}	8.34 ^{a}	19.79 ^{f}	16.33 ^{c}	4.9 ^{j}	0.90 ^{d}
	3.0	53.72^{f}	1.34 ^{c}	7.21 ^{b}	20.32 ^{e}	16.59 ^{b}	5.4 ^{h}	1.05 ^{b}
	4.0	55.51^{e}	1.98 ^{b}	7.34 ^{b}	21.77 ^{b}	12.48 ^{f}	6.1 ^{c}	0.90 ^{d}

SCN	**2.0**	53.99 f	2.15 b	6.10 e	20.01 e	17.44 a	5.9 e	1.10 a
	3.0	56.99 d	2.43 a	7.30 b	20.00 e	12.05 g	5.7 g	0.95 d
	4.0	57.65 c	1.94 b	5.90 e	19.52 f	14.03 e	6.2 b	0.88 e
Control	_	53.06 f	2.44 a	6.69 c	22.36 a	14.81 d	5.8 f	1.17 a
SEM	_	0.191	0.103	0.112	0.181	0.121	_	_

abcdefghij means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, MC=Moisture content, EE=Ether Extract, CP=Crude Protein, pH= Potential Hydrogen,TBA= Thiobarbituric Acid.

The ash content of SCCat 2%, 3%, the control, and SCN at 3% were higher (P<0.05) than the rest, with values of 2.54, 2.50, 2.44 and 2.43% respectively. This was followed by SCN at 2% (2.15%), SCA at 4% (1.98%), SCN at 4% (1.94%), which were all not significant (P>0.05). SCC at 4% and SCA at 2% followed closely, having values of 1.74 and 1.63 respectively and the least was SCA at 3% which had a value of 1.34%. The ether extract of SCA at 2% inclusion level was higher (P<0.05), with a value of 8.34% than the rest having values of 7.34% (SCAat 4%), 7.30% (SCNat 3%), 7.21% (SCAat 3%), 6.69% (control), 6.64% (SCCat 3%), 6.69% (control), 6.35% (SCC at 2%), 6.10% (*SCN*at 2%), 5.93% (SCC at 4%) and 5.90% (SCN at 4%).

For crude protein, thecontrol had higher (P<0.05) values of 22.36% than the rest which had values of 21.77% (SCA at 4%), 21.26% (SCC at 4%), 20.69% (SCC at 2%). SCA at 3%, SCN at 2 and 3%, having values of 20.32, 20.01 and 20.00% respectively, followed by SCA at 2% and SCN at 4% which were also not different (P>0.05) having values of 19.79 and 19.52% respectively. The least was SCC at 3% (18.62%). For NFE, values ranged between 6.60– 17.44 with the least value being SCC at 4% and the highest value being SCNat 2% inclusion level. The pH values showed the four treatments at all inclusion levels to have been statistically (P<0.05) significant with values which ranged between 4.9-6.4. TBA value across all treatments and their varied levels was also statistically (P>0.05) significant, having values which ranged between 0.88-1.17mg/100g.

4.11: Effect of treatment, inclusion level and interaction on the organoleptic properties of *suya* on day one sampling period

Table 4.11 shows the mean effects of the treatment, inclusion level and their interaction on the organoleptic properties of *suya* on day one sampling period. Flavor of SCN and SCA was significantly (P<0.05) higher (6.92 and 6.72 respectively) than the control (6.43) and SCC(5.94). In terms of juiciness, SCAwas significantly (P<0.05) higher (6.89) than the other treatments which had values of 6.60 (control), 6.43 (SCN) and the least, 6.26 (SCC). Overall acceptability was higher (P<0.05) in SCA (7.29) than SCN

Table 4.11: Effect of treatment, varied inclusion levels and interaction on the organoleptic properties of *suya* on day one sampling period

Treatments	Colour	Flavour	Tenderness	Juiciness	Overall acceptability
Spices					
SCC	6.23	5.94^{b}	6.48	6.26^{b}	6.44^{c}
SCA	6.74	6.92^{a}	6.97	6.89^{a}	7.29^{a}
SCN	6.56	6.78^{a}	6.50	6.43^{ab}	7.08^{ab}
Control	6.70	6.43^{ab}	6.23	6.60^{ab}	6.67^{bc}
SEM	0.193	0.204	0.220	0.201	0.202
Inclusion (%)					
2	6.26	6.59	6.62	6.52	6.98
3	6.71	6.60	6.64	6.46	6.80
4	6.57	6.46	6.68	6.60	7.03
SEM	0.193	0.204	0.220	0.201	0.202
Interaction					
Spices*inclusion	NS	NS	NS	NS	NS

^{abc} means within column having different superscripts differed significantly ($P<0.05$). SCC = Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means.

(7.08), control (6.67) and SCC (6.44). Colour and tenderness did not differ (P>0.05). At varied inclusion levels, values although numerically different, were not significant (P>0.05).

Interaction effects between the treatments and the inclusion levels on day one sampling period were not significant (P>0.05) across all the parameters.

Table 4.12: Effects of treatment, varied inclusion levels and their interaction on the organoleptic property of *suya* on day four sampling period

Table 4.12 shows the effect of the treatment, inclusion level and their interaction on the organoleptic properties of *suya*, on day four sampling period. *Suya* when coated with spices of interest had no significant difference (P>0.05) on colour, flavour, juiciness, tenderness and overall acceptability values. At all three inclusion levels (2, 3 and 4%), no differences was also recorded.

4.13: Effects of treatment, varied inclusion levels and their interaction on the organoleptic property of *suya* on day seven sampling period

Table 4.13 shows the effect of the treatment, inclusion level and their interaction on the organoleptic properties of *suya* on day seven sampling period. *Suya* prepared with the four treatments (SCC, SCA, SCN and the control) had no significant (P>0.05) effect on colour, flavor, juiciness, tenderness and overall acceptability. For the inclusion levels, values across all other parameters except colour did not differ (P> 0.05). For colour, *suya* marinated at 3% inclusion level was significantly (P<0.05) higher than those at 2% inclusion level (5.86) and that of 4% inclusion level (5.71).

4.14: Interaction effect between the treatment and varied inclusion levels on the organoleptic properties of *suya* on day four sampling period

Table 4.14 shows the interaction effects of treatments and levels on the organoleptic properties of *suya* on day four sampling period.

SCN at 2% inclusion level, SCC at 3 and 4% inclusion level, SCA at 2, 3 and 4 % inclusion level, and the control were all similar (P>0.05) and rated highly for color, having values of 6.43, 6.33, 6.27, 6.13, 6.43, 6.23 and 6.17 respectively, while SCN at 3 and 4% inclusion level followed closely having values of 6.23 and 5.87 respectively, and the least was SCC at 2% inclusion level which had a value of 4.83.

Table 4.12: Effects of treatment, varied inclusion levels and their interaction on the organoleptic property of *suya* on day four sampling period

Treatments	Colour	Flavour	Tenderness	Juiciness	Overall acceptability
Spices					
SCC	5.81	5.83	5.78	5.90	6.57
SCA	6.27	6.17	6.30	6.53	6.71
SCN	6.18	6.23	6.22	6.40	6.94
Control	6.17	6.27	5.67	6.47	6.67
SEM	0.211	0.236	0.231	0.227	0.214
Inclusion (%)					
2	5.80	5.86	5.74	5.97	6.42
3	6.33	6.26	6.37	6.46	6.91
4	6.12	6.12	6.19	6.41	6.89
SEM	0.211	0.236	0.231	0.227	0.214
Interaction					
Spices*Inclusion	**	**	**	**	NS

SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, NS=Not Significant.

Table 4.13: Effects of treatment, varied inclusion levels and their interaction on the organoleptic property of *suya* on day seven sampling period

Treatments	Colour	Flavour	Tenderness	Juiciness	Overall acceptability
Spices					
SCC	5.74	5.80	6.07	6.06	6.29
SCA	6.04	6.07	6.10	6.43	6.53
SCN	6.12	6.30	6.14	6.41	6.64
Control	5.87	6.10	5.77	6.03	6.53
SEM	0.183	0.189	0.204	0.186	0.185
Inclusion (%)					
2	5.86 [ab]	6.03	5.78	6.12	6.46
3	6.34 [a]	6.19	6.32	6.41	6.58
4	5.71[b]	5.94	6.21	6.37	6.43
SEM	0.183	0.189	0.204	0.186	0.185
Interaction					
Spices*Inclusion	NS	NS	**	**	NS

[ab] means within column having different superscripts differed significantly ($P<0.05$), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means., NS=Not Significant.

Table 4.14: Interaction effect between the treatment and varied levels of inclusion on the organoleptic properties of *suya* on day four sampling period

Treatments	Level	Colour	Flavour	Tenderness	Juiciness	Overall acceptability
SCC	**2.0**	4.83 [b]	4.77 [b]	4.87 [b]	4.63 [b]	5.80
	3.0	6.33 [a]	6.33 [a]	6.20 [a]	6.63 [a]	6.83
	4.0	6.27 [a]	6.40 [a]	6.27 [a]	6.43 [a]	7.07
SCA	**2.0**	6.13 [a]	6.13 [a]	6.23 [a]	6.57 [a]	6.47
	3.0	6.43 [a]	6.27 [a]	6.70 [a]	6.67 [a]	6.97
	4.0	6.23 [a]	6.10 [a]	5.97 [ab]	6.37 [a]	6.70
SCN	**2.0**	6.43 [a]	6.67 [a]	6.13 [a]	6.70 [a]	7.00
	3.0	6.23 [ab]	6.17 [a]	6.20 [a]	6.07 [a]	6.93
	4.0	5.87 [ab]	5.87 [ab]	6.33 [a]	6.43 [a]	6.90
Control	**_**	6.17 [a]	6.27 [a]	5.67 [ab]	6.47 [a]	6.67
SEM		0.298	0.334	0.327	0.321	0.302

[ab] means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means.

For flavour, SCN at 2 and 3% inclusion level, SCC at 3 and 4% level of inclusion, SCA at 2, 3 and 4 % inclusion level, and the control were all similar (P>0.05) and rated higher than the rest having values of 6.67, 6.17, 6.33, 6.40, 6.13, 6.27, 6.10 and 6.27 respectively, this was followed by SCN at 4% level of inclusion and the least being SCC at 2% level of inclusion.

Tenderness was significantly (P<0.05) high in SCN at 2, 3 and 4% level of inclusion, SCC at 3 and 4% level of inclusion and SCA at 2 and 3% level of inclusion having values of 6.13, 6.20, 6.33, 6.20, 6.27, 6.23 and 6.70 respectively, this was followed by the control and SCA at 4% inclusion level whose values were 5.67 and 5.97 respectively, while the least rated for tenderness was SCC at 2% level of inclusion. As per juiciness, except for SCC at 2% (4.63), the rest were similar (P>0.05) with values of 6.07 (SCN at 3%), 6.37 (SCA at 4% inclusion level), 6.43 (SCN and SCC at 4% inclusion level), 6.47 (control), 6.57 (SCA at 2% inclusion level), 6.63 (SCC at 3% inclusion level), 6.67 (SCA at 3% inclusion level), and 6.70 (SCN at 2% inclusion level). Overall acceptability means of *suya* on day four sampling period were not statistically significant (P>0.05).

4.15: Effects of interaction between treatments and varied inclusion levels on the organoleptic properties of *suya* on day seven sampling period

Table 4.15 shows the interaction effects of treatments and levels on the organoleptic properties of *suya* on day seven sampling period. Asides from mean values of juiciness and tenderness which were significant (P<0.05), color, aroma and overall acceptability were not significant. In terms of tenderness, SCA at 3% level of inclusion (6.77), SCN at 4% level of inclusion (6.57), SCC at 4% inclusion level (6.47) and SCN at 3% inclusion level (6.20) were all at par (P>0.05), this was followed by SCC at 3% level of inclusion (6.00), and the least (P<0.05) were the SCA at 2% level of inclusion (5.93), the control (5.77), SCC at 2% level of inclusion (5.73), SCN at 2% level of inclusion (5.67), and SCA at 4% (5.60).

Table 4.15: Effects of interaction between treatments and varied inclusion levels on the organoleptic properties of *suya* on day seven sampling period

Treatments	Level	Color	Aroma	Tenderness	Juiciness	Overall Acceptability
SCC	2.0	5.57	5.83	5.73 [b]	6.07 [b]	6.40
	3.0	6.10	5.50	6.00 [ab]	5.70 [b]	6.00
	4.0	5.57	6.07	6.47 [a]	6.40 [ab]	6.47
SCA	2.0	6.00	6.23	5.93 [b]	6.20 [b]	6.50
	3.0	6.57	6.33	6.77 [a]	7.17 [a]	6.90
	4.0	5.57	5.63	5.60 [b]	5.93 [b]	6.20
SCN	2.0	6.00	6.03	5.67 [b]	6.10 [b]	6.47
	3.0	6.37	6.73	6.20 [a]	6.37 [ab]	6.83
	4.0	6.00	6.13	6.57 [a]	6.77 [a]	6.63
Control	_	5.87	6.10	5.77 [b]	6.03 [b]	6.53
SEM		0.259	0.267	0.288	0.263	0.263

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[ab] means within column having different superscripts differed significantly ($P<0.05$), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means.

Juiciness of *suya* treated with the four treatments had higher significant (P<0.05) values in SCA at 3% and SCN at 4% level of inclusion (7.17 and 6.77 respectively), this was followed by SCN at 3% and SCC at 4% level of inclusion (6.37 and 6.40 respectively), which were both also statistically alike, and the least were SCA at 2% level of inclusion, SCN at 2% level of inclusion, SCC at 2% level of inclusion, the control, SCA at 4% level of inclusion and SCC at 2% level of inclusion which had values of 6.20, 6.10, 6.07, 6.03, 5.93 and 5.70 respectively. Overall acceptability means of *suya* on day seven of the sampling period were not statistically significant (P>0.05).

4.16: Effect of treatment, varied inclusion levels and their interaction on the microbial properties of *suya* on days one, four and seven sampling period

Table 4.16 shows an overview effects of all four treatments, their varied inclusion levels and interaction effects on the microbes.

On day one, TVBC (Total viable bacteria count) of SCC was significantly (P<0.05) more than those of SCN, SCA and the control which was observed to have been statistically similar, with values which ranged between log 1.70 in SCN and log 3.11 in SCC.

On day four, TVBC of the control with a log value of 6.18 was significantly (P<0.05) more than those coated with spices which were all statistically at par. SCC (log 4.83) followed closely and SCN and SCA were the least significant and having log values of 4.04 and 3.82 respectively. On day seven sampling period, SCC was significantly higher having a log value of 8.50. This was followed by SCN (log 7.75), the control (log 7.43) and the least was SCA (log 5.71). Inclusion level on day one sampling period showed *suya* at all three inclusion levels to have been at par (P>0.05) and so not significantly different. With *suya* prepared at 2, 3 and 4% having log values of 2.36, 2.16 and 2.40respectively. Sampling on day four also had values which were not significant with that of 2% inclusion level having a log value of 4.26, 3% inclusion level was log 4.14 and that of 4% had a log value of 4.30.

Table 4.16: Effect of treatment, varied inclusion levels and their interaction on the microbial properties of *suya* on days one, four and seven sampling period

Treatments	TVBC			Coliform Count			Total Yeast Count			Total Mold Count		
Days	1	4	7	1	4	7	1	4	7	1	4	7
<u>Spices</u>												
SCC	1.70^{c}	4.04^{b}	7.75^{b}	2.09	3.26	7.11^{a}	ND	ND	3.89^{b}	ND	ND	4.33^{b}
SCA	3.11^{a}	4.83^{b}	8.50^{a}	2.45	3.78	6.91^{ab}	ND	ND	4.64^{a}	ND	ND	5.86^{ab}
SCN	2.78^{ab}	6.18^{a}	7.43^{b}	2.29	3.90	6.36^{b}	ND	ND	4.15^{ab}	ND	ND	6.14^{a}
Control	2.11^{bc}	3.82^{b}	5.71^{c}	2.12	3.21	3.61^{c}	ND	ND	0^{c}	ND	ND	0^{c}
SEM	0.2972	0.3828	0.2149	0.2077	0.2965	0.2121	_	_	0.7666	_	_	0.8983
<u>Inclusion (%)</u>												
2	2.36	4.26	7.53^{a}	2.07	3.36	5.93^{a}	ND	ND	2.89	ND	ND	3.49
3	2.16	4.14	6.78^{b}	2.23	3.44	5.27^{b}	ND	ND	2.75	ND	ND	3.27
4	2.40	4.30	7.44^{a}	2.36	3.45	5.92^{a}	ND	ND	2.89	ND	ND	3.43
SEM	0.2972	0.3828	0.2149	0.2077	0.2965	0.2121	_	_	0.7666	_	_	0.8983
<u>Interaction</u>												
Spices*Inclusion	*	NS	NS	*	*	**	-	-	**	-	-	**

^{abc} means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, TVBC= Total Viable Bacteria Count, NS=Not Significant, ND=Not Detected. Log <100=1, log <1,000=2, log <10,000=3, log <100,000=4, log <1,000,000=5, log< 10,000,000=6.

On day seven sampling period, values were significant (P<0.05) across the three varied levels of inclusion, with that included at 3% inclusion level being the least (P<0.05) having a mean value of log 6.78, while those included at 2% and 4% were at par (P>0.05) having respective log values of 7.53 and 7.44. Interaction between treatments and the three inclusion levels was significant (P<0.05) on sampling day one, four and seven.

For coliform counts, values on day one and day four were not significant (P>0.05). On day seven however, SCNwas significantly more (P<0.05) at log 7.11, than SCC, control and SCA having values of log 6.91, 6.36 and 3.61 respectively. Inclusion level on day one and day four sampling period showed values that were not significant (P>0.05) however that of day seven was. On day seven, *suya*coated at 3% inclusion level was significantly (P<0.05) less (log 5.27) than those of 2% inclusion level (log 5.93) and 4% inclusion level (log 5.92) which were both similar. Interaction between treatments and the three inclusion levels was significant (P<0.05) on sampling day one and seven, but means were not significant on day four.

For total yeast counts, nothing was detected on days one and four sampling period, however on day seven, yeast counts were detected and means were significant. SCCwas significantly (P<0.05) more (log 4.64) than that of the control (log 4.15), SCN (log 3.89) and SCA (nothing detected). At varied inclusion levels, no count was detected on sampling days one and four, however on day seven, yeast counts were detected but means were all similar. Interaction between treatments and the three inclusion levels was significant (P<0.05) across means detected on sampling day seven as no yeast count was detected on sampling days one and four.

For mold counts, nothing was detected on days one and four sampling period, however on day seven, the control was significantly (P<0.05) more (log 6.14) than that of SCC (log 5.86),SCN (log 4.33) and the SCA(no detectable count).

At varied inclusion levels, no count was detected on sampling days one and four, however on day seven, mould counts were detected but means were not significant (P>0.05). At Interaction between treatments and the three inclusion levels, no mold count was detected on sampling days one and four. However mould counts were significant (P<0.05) across means on sampling day seven.

4.17: Interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day one sampling period

Table 4.17 shows the effects of interaction between the treatments and the varied levels of inclusion on the microbial properties of *suya* on day one sampling period.

SCCat 2% and 4% inclusion level was significantly (P<0.05) more (3.19 and 3.25 respectively) in TVBC than that of SCC at 3% level of inclusion (2.89), control (2.78), SCA at 4% level of inclusion (2.17), SCAat 2% level of inclusion (2.15), SCA at 3% level of inclusion (2.03) and the least were SCN at 2%, 3% and 4% level of inclusion (1.75, 1.57 and 1.77 respectively) which were all similar.

Coliform count was significantly more (P<0.05) in SCCat 3% and 4% inclusion level (2.63 and 2.57 respectively), and this was followed by the control, SCN at 3% and 4% inclusion level, SCC at 2%, and SCA at 2% and 4% level of inclusion which were all similar and had means of 2.29, 2.15, 2.33, 2.15, 2.27 and 2.19 respectively. SCN at 2%and SCAat 3% inclusion level were the least and had values of 1.79 and 1.91 respectively.

4.18: Interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day four sampling period

Table 4.18 shows the effects of interaction between the treatments and the varied levels of inclusion on the microbial properties of *suya* on day four sampling period. There was a significant (P<0.05) difference across the means of Total viable bacteria count, and the coliform counts. Fungal counts showed zero counts detected on day four.

Table 4.17: Interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day one sampling period

Treatments	Level	TVBC	Coliform Count	Total Yeast Count	Total Mold Count
SCC	**2.0**	3.19 [a]	2.15 [ab]	ND	ND
	3.0	2.89 [ab]	2.63 [a]	ND	ND
	4.0	3.25 [a]	2.57 [a]	ND	ND
SCA	**2.0**	2.15 [bc]	2.27 [ab]	ND	ND
	3.0	2.03 [bc]	1.91 [b]	ND	ND
	4.0	2.17 [bc]	2.19 [ab]	ND	ND
SCN	**2.0**	1.75 [c]	1.79 [b]	ND	ND
	3.0	1.57 [c]	2.15 [ab]	ND	ND
	4.0	1.77 [c]	2.33 [ab]	ND	ND
Control	**_**	2.78[b]	2.29 [ab]	ND	ND
SEM		0.4203	0.2938	ND	ND

[abc] means within column having different superscripts differed significantly ($P<0.05$), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, TVBC= Total Viable Bacteria Count, ND= Not detected. Log <100=1, log <1,000=2, log <10,000=3, log <100,000=4.

Table 4.18:Interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day four sampling period

Treatments	Level	TVBC	Coliform Count	Total Yeast Count	Total Mold Count
SCC	**2.0**	4.85 [b]	3.68	ND	ND
	3.0	4.74 [b]	3.88	ND	ND
	4.0	4.91 [b]	3.79	ND	ND
SCA	**2.0**	3.87 [c]	3.16	ND	ND
	3.0	3.66 [c]	3.22	ND	ND
	4.0	3.92 [c]	3.25	ND	ND
SCN	**2.0**	4.05 [bc]	3.24	ND	ND
	3.0	4.02 [bc]	3.22	ND	ND
	4.0	4.06 [bc]	3.32	ND	ND
Control	**_**	6.18[a]	3.92	ND	ND
SEM		0.5414	0.4193	ND	ND

[abc]means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, TVBC= Total Viable Bacteria Count, ND= Not detected. Log <100=1, log <1,000=2, log <10,000=3, log <100,000=4, log <1,000,000=5, log< 10,000,000=6.

For total viable bacteria counts, results showed the control, was significantly (P<0.05) more (6.18), having the highest microbial count on day four. This was followed by that prepared with SCN at 2%, 3%, and 4% and SCC at 2%, 3% and 4% level of inclusion which had values of 4.05, 4.02, 4.06, 4.85, 4.74 and 4.91 respectively and were statistically at par. The least were those marinated with SCA at 2%, 3% and 4% inclusion level which had values of 3.87, 3.66, and 3.92 respectively.

For coliform counts, results showed *suya* prepared with the treatments at all three levels of inclusion to not have had any significant difference across means.

4.19: Shows the interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day seven sampling period

Table 4.19 shows the effects of interaction between the treatments and the varied levels of inclusion on the microbial properties of *suya* on day seven sampling period. There was a significant (P<0.05) difference across the means of Total viable bacteria count, coliform counts and fungal counts.

TVBC counts were significantly (P<0.05) higher in SCN at 2% inclusion level and SCC at 2, 3 and 4% inclusion level which had values of 7.96, 8.86, 8.00, and 8.65 respectively. This was followed by the control and SCN at 3 and 4% inclusion level, which were statistically at par and had respective values of 7.43, 7.45 and 7.85. SCA at 2%, 3% and 4% which had respective values of 5.79, 5.52 and 5.83.

Coliform count was significantly (P<0.05) more in *suya* prepared from SCN at all three levels of inclusion and SCC at 2% and 4% inclusion level (7.04, 7.15, 7.13, 7.08 and 7.02) which were all statistically similar. This was followed by the control and SCC at 3% level of inclusion which were both statistically at par having values of 6.36 and 6.62. The least was SCA at all three levels of inclusion which had values of 3.67, 3.53 and 3.61 respectively.

For total yeast count, results showed SCC at 2%, 3% and 4% inclusion level, to have been significantly (P<0.05) more with a value of 4.52, 4.72, 4.69 respectively.

Table 4.19: **Interaction effect between treatments and varied inclusion levels on the microbial properties of *suya* on day seven sampling period**

Treatments	Level	TVBC	Coliform count	Total yeast count	Total mould count
SCC	**2.0**	8.86 [a]	7.08 [a]	4.52 [a]	6.05 [a]
	3.0	8.00 [a]	6.62 [b]	4.72 [a]	5.63 [b]
	4.0	8.65 [a]	7.02 [a]	4.69 [a]	5.89 [ab]
SCA	**2.0**	5.79 [c]	3.67 [c]	ND	ND
	3.0	5.52 [c]	3.53 [c]	ND	ND
	4.0	5.83 [c]	3.61 [c]	ND	ND
SCN	**2.0**	7.96 [a]	7.04 [a]	4.14 [ab]	4.42 [c]
	3.0	7.45 [b]	7.15 [a]	3.54 [b]	4.18 [c]
	4.0	7.85 [b]	7.13 [a]	3.98 [b]	4.39 [c]
Control	**_**	7.43 [b]	6.36 [b]	4.15 [ab]	6.14 [a]
SEM		0.3039	0.2999	1.0841	1.2704

[abc] means within column having different superscripts differed significantly (P<0.05), SCC= Suya containing SCC, SCA= Suya containing SCA, SCN= Suya containing SCN, Control= Suya having none of the spices of interest, SEM= Standard Error of Means, TVBC= Total Viable Bacteria Count, ND= Not Detected. Log <100=1, log <1,000=2, log <10,000=3, log <100,000=4, log <1,000,000=5, log< 10,000,000=6, log< 100,000,000=7, log <1,000,000,000=8.

This was followed by the control and SCN at 2% which had respective values of 4.15 and 4.14. SCN at 3% and 4% had values of 3.54 and 3.98 while SCAat all three levels of inclusion had no yeast counts detected for day seven.

For total mould counts, results showed the control and also SCCat 2% being significantly (P<0.05) more with a value of 6.14 and 6.05 respectively. This was followed by SCC at 4% with a value of 5.89, SCCat 3% which had a value of 5.63, and SCNat 2%, 4% and 3% which had respective values of 4.42, 4.39 and 4.18. SCAat all three levels of inclusion had zero mould counts detected for day seven.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Proximate composition of the test ingredients

Results obtained for the proximate composition of the seeds (Table 4.1), fornegro pepper, values for thecrude protein, moisture content, carbohydrate and ash contents were in consonance with the report of Imo *et al.* (2018), however the crude fibre and ether extract differed widely. This may have been due to different stages of maturity at the time of harvesting, as that could have made the seeds become fibrous. The results for cloves differed from values of other authors (Ogunka-Nnoka and Mepba, 2008; Bello and Jimoh 2012; Suleiman and Anas 2017) and this could be attributed to factors ranging from different ecological zones, harvesting period, edaphic and climatic influences which has been proven to have effects on the proximate composition of plants. The results obtained for ashanti pepper showed high carbohydrate and mineral contents and this corroborated with findings of Okeke *et al.* (2018)

5.2Proximate composition of fresh beef

The values obtained for proximate composition offresh beef (Table 4.2) in this study is similar to that reported by Rendle and Keeley (1998) as cited by Gandi (2014), for dry matter, moisture content, NFE and ash. Though it was slightly lower in crude protein and higher in ether extract.This variation could be attributed to the breed, the part of the body where the meat was obtained and feed given to the bull.

5.3 Microbial properties of fresh beef

The values obtained in microbial properties offresh beef (Table 4.3) in this study was lower for total viable bacteria count and coliform count respectively, than the values of same (4.49×10^7 and 2.95×10^8 respectively), as reported by Chuku *et al.* (2016). The variation could be attributed to the handling of the meat before processing and during analysis.

5.4 Physical changes in the final product (*suya*) from the initial product

The values obtained in physical changes in the final product from the initial product (Table 4.4), shows a significant decrease in pH, this could have been as a result of the processing method (grilling) but corresponded with values reported by Gandi (2014). A drop in pH causes the production of lactic acid which increases acidity, thus lactic acid serves as a preservative, lessening deterioration. Also the weight, length and thickness significantly decreased and this was to be expected as moisture was lost during processing. Average cooking loss and average thermal shortening were both lower than values reported by Kassim (2013) in his work on meat floss, an IMM.

5.5 Effect of treatments andvaried levels of inclusion on the physico- chemical properties of *suya* at day one of sampling

From the result for the moisture content in this study, it could be postulated that the spices having their own moisture might have influenced this. The values from this study however disagreed with values reported by Edema *et al.* (2008), Abubakar *et al.* (2011) and Egbebi and Seidu (2011). The inclusion levels showed the moisture content reduced as inclusion level increased and this shows a proportional relationship between moisture content and inclusion level at day one sampling period.

The ash content values was in agreement with works reported by Igene and Abulu (1983) but disagreed with values reported by Abubakar *et al.* (2011) and Apata *et al.* (2013) who all worked on *suya*. Mineral values increased in the processed product from that of the raw/fresh meat and this increase could be attributed to the heat treatment which the *suya* was subjected to. Igene and Ekanem (1985) reported that ash content of meat increases during heat application.

The ether extract content was comparable with 5.89-7.98% reported by Gandi (2014) and 7.96-8.70% reported by Oyadeyi *et al.* (2014). The fat content of *suya* in this study was less than 10% and compared to the acceptable level of fat in raw meat; this may imply that low ether extract obtained in this study resulted from the low-fat content of fresh meat used (Oyadeyi *et al.*, 2014). The higher fat content observed in the control could be attributed to the spices anti-oxidative properties or the low moisture and fat content relationship as suggested by Fakolade (2012), since they relate inversely.

Crude protein is indicative of the nutritional quality of a product. The crude protein in this study was higher than that contained in the fresh meat. This supports reports by Egbunike and Okubanjo (2000), that IMM are low in moisture content, less bulky and have higher protein than raw meat protein equivalent. The low crude protein value obtained in this study may be due to effect of smoke on crude protein as Gandi (2014) citing Okonkwo *et al.* (1992) reported that smoking leads to a slight loss of some of the protein though he did not state the temperature at which this will occur. The Crude protein content in all the sampling days was highest in the control and least in the SCN. The reason for the high content of crude protein in the control could have been as a result of the spices not been present to dilute the nutrient composition of the *suya*. Inclusion levels had no significance on the *suya* product.

Nitrogen Free Extract (NFE) shows the availability of soluble carbohydrate in a food product. The control was the least and SCN being the highest and the reason for this could be postulated to have been as a result of the fibrous nature of the spices especially the SCN.

The estimation of pH in meat is of value in determining durability and when meat reaches a pH of 6.4, decomposition may set in and at 6.8 and above, the signs of decomposition viz., changes in colour, odour and texture may become apparent, Thus pH of meat has a significant relationship to eating quality (Govindarajulu, 1989). The pH values on day one agrees with values reported by Haruna (2014) (5.38-5.99) and Gandi (2014) (5.70-6.50). Inclusion levels had significance on the *suya* treatments.

The estimation of oxidative rancidity is one of the methods to assess the stability of any food product containing lipids. TBA values disagreed with values (0.13-0.44mg/100g) reported by Haruna (2014) who worked on chicken patties, although he also reported same occurrence of the least being the control. It could thus be postulated that spices has a role to play in increasing the TBA value of animal products. Inclusion levels had no significance on the *suya* product.

5.6 Effect of treatments and varied levels of inclusion on the physico- chemical properties of *suya* on day four sampling period

The moisture content on value showed a steady decline from the day one and this was not unexpected as it corresponded with Oyadeyi *et al.* (2014) report of steady decline in moisture content of *suya* as days of storage lengthened and Ogunsola (2006) who also in his work on *kilishi* (an IMM product) reported same decline in moisture content as days lengthened. The longer the *suya* was kept exposed at room temperature, expected escape of moisture and resulting toughness of the *suya* took place. Inclusion levels showed an arbitrary trend on the *suya* samples and the reason for this is not known.

Ash content showed SCA samples to be the least and the control was the highest. Oyadeyi *et al.* (2014), similarly reported an increase in the ash content of their control that had no *Occimum gratissimum* extract as the days lengthened. This is not quite clear as it would have been expected that the spices would have infused some of their minerals into the *suya*, thus increasing the ash content. At varied levels of inclusion, it could be postulated that an increased inclusion level caused an increased mineral content in the *suya.*

Ether extract content decreased from that obtained at day one and the reason for this could be because in aroma development of meat, fat is very important but as the meat ages the fat deteriorates through microbial attack, tissue enzyme activity and oxidation of unsaturated bonds, this results in the development of bad odours and deterioration of taste (Gandi, 2014). Inclusion levels showed values steadily increasing as inclusion levels increased thus showing a proportionate relationship between treatment and inclusion levels in day four.

Crude protein showed only a slight decrease from that obtained in sample day one and inclusion levels had no significance on the *suya* product.NFE value range could be as a result of the fibrous nature of the SCN, however inclusion levels followed no pattern.

Values of pH showed spices played little role in keeping the *suya* samples acidic. Inclusion levels showed an inverse relationship and had values which decreased as the inclusion levels increased. In this study, despite a significant microbial increase, major changes in pH values across sampling days were not observed.

5.7 Effect of treatments and varied levelsof inclusion on the physico- chemical properties of *suya* on day seven sampling period

As sampling days lengthened, moisture content values dropped. At sampling day seven (Table 4.7) the control still being the least and the highest still that marinated with the SCC, thus showing a consistent trend. Values of inclusion also increased as inclusion levels increased and this observation is in line with works by Biswas *et al.* (2011) in duck patties, Abdolghafour and Saghir (2014), in buffalo meat sausages and Oyadeyi *et al.* (2014) on *suya* processed with *Occimum gratissimum* and stored for a seven day period.

The decrease in moisture content was directly proportional to a decreased protein content as the days increased, and could have been as a result of loss of drip fluid during storage and also evaporation of moisture from meat in the chilled ambient environment where the meat was stored.

Ash content values gotten from this study was in correspondence with values (1.71-2.21) reported by Oyadeyi *et al.* (2014) in their work on meat patties treated with *O. gratissimum* and 2.31- 2.86 reported by Adeyeye *et al.*(2016) in their work on smoked tilapia fish. On day four and seven, the highest on both days was the control and the least was SCA. The control performing best on day four and seven showed a decline in the potency of the spices and thus, mineral content of the *suya*. Although SCC seeds was high in mineral content, it did not play a significant part in the ash content of the *suya* and the reason for this could have been the quantity at which it was included. At varied levels of inclusion, the highest inclusion level of 4% gave the highest value on days one and four, however, on day seven, 2% gave the highest. For the days one and four, result gotten for ash content was expected as the mineral contained in the spices on inclusion at such high levels would have been infused into the *suya* during processing. Over the 7-day storage duration there was a steady increase in the ash values and this occurrence agrees with works by Oyadeyi *et al.* (2014), Kassim (2014) and Daramola (2018) who reported similar trends of increased mineral content in their animal products as storage lengthened.

As the days lengthened, for ether extract value in this study, an observed decrease in the moisture content and increase in the total fat content of the products is seen and this agreed with the results from works of Oyadeyi *et al.* (2014), Kassim (2012), Badiani *et al.* (2002) and Kesava *et al.* (1996) who found that losses in the moisture content resulted in higher dry matter and increased content of total lipid and other components in cooked meat samples.

NFE values was quite high as opposed to the raw meat value, with SCA being the highest and SCC being the least. Thus the product on day seven contained an increased level of soluble carbohydrate, thus affecting the crude protein which declined even as it increased. In this study, an inverse relationship existed between the Nitrogen Free Extract and the crude protein.

Crude protein values showed a decrease in the C.P content of the product as the days of storage increased, thus corresponding with similar trends observed by Oyadeyi *et al.* (2014), Adenike (2014), Akharaiyi and Isunu (2015), and Daramola (2018), in their works on processed animal products, who all reported a decrease in protein levels as the duration of storage lengthened. Adenike (2014), postulated that such occurrence could have been as a result of increase in dry matter content following processing, while Naveen *et al.* (2016), in their work postulated that such decrease in the crude protein could have been as a result of protein decomposition in the stored product.

Values for pH steadily declined as the days lengthened, however, all through the sampling days, the control maintained a steady pH value. The drop in pH is a desirable feature as a low pH slows down growth of micro-organisms and enhances aroma, juiciness and colour of the meat to give an attractive saleable product (Pearson, 2012). This decrease as the days increased however disagreed with reports by Kumar and Tanwar (2011) and Haruna (2014). For this present study, there was a decrease in the pH values as the days lengthened though not so much, suggested shelf life stability and agreed with Eke *et al.* (2012) report on stored *dambu-nama* citing Rustom *et al.*(1995), adduced reasons attributed to protein-protein reactions during storage leading to the release of free H+. It could also be that due to microbial activity in the decomposition of the protein, there was an increase in the lactic acid production leading to a decrease in the pH of the *suya* product. There was also an increase in microbial population as well as fermentation of carbohydrate to acid as the days went by, thus leading to a decreased pH and a slightly acidic product. This decrease is in support of reports by Grajales-Lagunes *et al.* (2012) who reported that at 1% concentration level of lactic acid in pork stored at 4^0C for 7 days, there was a decrease in pH value. It might have resulted from the influence of the addition of plant extracts on directions of metabolic transformations of microorganisms and enzymes in the product (Jałosińska and Wilczak 2009). Russell *et al.* (1996) reported that meat of alkaline nature deteriorates faster than that of acidic nature, thus the reduction and resulting acidity was good because the treatments even at sampling day seven, most were still palatable organoleptic-wise, as scores shows.

TBA values however increased as the days increased. This increase as storage days lengthened corresponded with works by Haruna (2014), Kassim (2014), Alam *et al.* (2005) and Naveen *et al.* (2016). It has been reported that during storage TBA value increases due to the decomposition of the oxidized lipids (Alam *et al.* 2005, Devatkal and Mendiratta, 2001). Naveen *et al.* (2016) in their work on duck sausages postulated that an increase of TBA values could be as a result of oxidation of fatty acids during storage. In days one and four, the least in values was the control, and the reason is not known as it would have been expected that the addition of the spices would have played a role in decreasing the TBA value of the *suya*. However, on day seven, the least was SCC, which could have been because of its rich content of eugenol which has been proven to have great antioxidant constituents.

5.8 Effect of interaction of treatment and varied levels of inclusion on the proximate composition of *suya* on sampling day one

Moisture content values on day seven (Table 4.8) were however not in agreement with that reported by Apata *et al.* (2013). Ash content values observed on this day showed every treatment had higher ash content at 4% inclusion level and this could be because at such high levels, the minerals from the spices infused greatly into the *suya*.

Ether extract values agreed with reports of Ogunsola and Omojola (2008) in their work on *kilishi* an IMM product. It could be postulated from this result that the spices affected the ether extract content of the *suya* samples by reducing it. NFE content values showed the least being that of SCN at 4% and the reason is not known as it would have been expected that at such high levels, the fibrous nature of the SCN would have been infused into the *suya* samples.

Crude protein values are below that reported by Oyadeyi *et al.* (2014) and Abubakar *et al.* (2011), and goes to show that the control was better than *suya* marinated with spices in increasing the crude protein content of the product. The values of pH were in agreement with that reported by Haruna (2014) and shows the *suya* at this sampling day to have been slightly acidic.

TBA values range were however below that reported by Adeyeye (2016) who also worked on *suya* and Kassim (2013) who worked on meat floss. It could however be seen that rancidity was very low (almost non- existent) on day one sampling period.

5.9 Effect of interaction of treatment and varied inclusion levels on the proximate composition of *suya* on day four sampling.

Values for moisture content differed significantly from each other on day four sampling period and this values show an expected decrease from that of day one, although they fell outside the range of 45.33-48.03% reported by Oyadeyi *et al.* (2014) in their work on *suya*. Ash values agreed with Oyadeyi *et al.* (2014) in their work on meat patties. Ash content is an indication of the mineral content of the *suya* and in this study we see the control having the higher mineral content. This occurrence was contrary to expection as it was expected that the spices would have diffused into the meat.

Crude protein values were below that reported by Edema *et al.* (2008). The reason for this could be that the spices, due to some of their chemical constituents might have played an adverse role in reducing the crude protein content of the *suya*. NFE values increased from that observed in the raw meat at sampling day one, even as moisture and crude protein decreased. This shows that there was an inverse relationship between NFE, CP and MC.

Values obtained in this study corresponded with that reported by Olusola *et al.* (2012) and Idowu *et al.* (2010) in their work on beef *kilishi.* Values of pH shows that the spices at their different levels of inclusion were below the neutral point of the pH on day four and was slightly acidic. Values were in agreement with that reported by Sodzim (2012) who stored treated pork over a 9-day duration. Values for rancidity indices were low and this explains why the *suya* even at fourth day of storage was still acceptable to the sensory panelists, as off-odours had still not set in.

5.10 Effect of interaction of treatment and varied inclusion levels on the proximate composition of *suya* on sampling day seven

Moisture content steadily decreased across the sampling days. This occurrence is in support of report of Oyadeyi *et al.* (2014) who stored *suya* cured with *Occimum gratissimum* for a seven day period, and reported a decrease in moisture content at day seven from that of day one. Drip loss could be postulated as the reason for the loss in moisture content. Ash content however increased in this study as days of sampling lengthened. This occurrence was also reported by Oyadeyi *et al.* (2014) and could have been as a result of reduced moisture content which may have resulted in higher concentration of the minerals in the *suya*. Interaction effect on ether extract content of *suya* shows a random trend amongst the treatments which steadily decreased as the days lengthened. Crude protein values of the control decreased steadily as the days lengthened while amongst the other treatments and their varied levels of inclusion, there was no specific trend as they increased and decreased across sampling days arbitrary. Thus, we see a directly proportional relationship between moisture content and the crude protein content of the product. As the storage days lengthened there was a decomposition of protein in the stored product, and this supports report of Warriss (2000) as cited by Mahendrakar *et al.* (1988) that microbial growth in meat matrix leads to decomposition of proteins.

For NFE, there was a steady increase across all the levels and treatments as the sampling days increased, although values were below that reported by Gandi (2014). In pH, values decreased at the last day from the initial, thus becoming more acidic, but control remained constant. It could be postulated that the spices played a role in this. The drop in pH is a desirable feature as a low pH slows down growth of micro-organisms and enhances flavour, juiciness and colour of the meat to give an attractive saleable product (Pearson, 2012).

TBA values increased steadily as the sampling days lengthened and was highest in the day seven. This was expected and supported reports of several authors (Haruna, 2014 and Kassim, 2014). TBA lowest means was seen in *suya* marinated with SCN and SCC at 4% and its highest means was seen in the control, thus the spices could be postulated to have helped in rancidity reduction especially the SCCwhich gave the least means in all three inclusion levels, which could probably have been because of its rich content of eugenol which has been proven to have great antioxidant constituents.

5.11 Effect of treatments andvaried inclusion levels on the organoleptics properties of *suya* on day one sampling period

In organoleptic properties, day one sampling period showed significant difference ($P<0.05$) in flavour, juiciness and overall acceptability only. Flavor values for SCC rated least and that of SCA rated highest. In juiciness, values likewise rated least in SCC and highest in SCA. Same trend was seen in overall acceptability where SCC rated least and SCA was rated best. These value range however agreed with reports of Naveen *et al.* (2016). Values on day one were above the average (5/intermediate) and rated well on overall acceptability which goes to show that the sensory panelists found it much to their liking, but especially preferred that marinated with SCA.

The low scores of SCC reflects that the panelists did not find the SCC appealing. Inclusion levels showed no significant differences (P>0.05) in all the parameters, thus organoleptic-wise, the inclusion levels of 2, 3 and 4% on day one was acceptable. This supports established facts that spices should not be put in too much quantity so as to not to mask the primary smell and taste of a meat product (Zaika, 1999).

5.12 Effect of treatments and varied inclusion level on the organoleptics properties of *suya* on day four sampling period

Mean values across parameters and inclusion level on day four (Table 4.12) were not significant, although values dropped from that observed in day one.

5.13 Effect of treatments andvaried inclusion level on the organoleptics properties of *suya* on day seven sampling period

Values across all the sensory parameters were not significant at sample day seven, although means decreased from that observed on day one, but at varied inclusion level, colour was significant, with 3% rating better. Mancini and Hunt (2005) reported microbial growth to be one of the factors that affects colour stability and causes discolouration. Colour and flavour, are the first determining factor of any meat and meat product (Anjaneyulu *et al.*, 2007) and this agreed with the relationship observed in this study as the product was still very much appealing to the panelist even at the day seven, rating above average. The decrease in flavour values supports the proximate decreasing values in crude protein content because in flavour development, proteins, lipids and carbohydrates play key roles as they include numerous compounds which develops into important flavour precursors (Spanier and Miller, 1993; Mottram, 1998; Brewer 2006). Stetzer *et al.* (2006) reported that positive flavour compounds decrease with aging and negative compounds increases.

On a general note, the final values across all the parameters decreased significantly from the first day values and this agrees with values and observation reported by Naveen *et al.* (2016). However, the juiciness for the SCNincreased although not significantly as the days increased. This could have been as a result of a decrease in flavour intensity in the SCN as the days increased. From this present study, SCC was rated as the worst performing in organoleptic properties. Also, the fact that there was not much significant difference in sensory attributes across treatments and their varied inclusion levels with values being above average across the sampling periods as this study proves, shows that these three spices can be used in the processing of *suya*.

5.14 Effects of interaction between treatments and varied inclusion level on the organoleptic properties of *suya* on day four sampling period

Values across means for color was significant, with the least being that marinated with SCC at 2% being the least and that marinated with SCN at 2% and SCA at 3% being the highest. Colour is the first determinant of accepabilty of any meat product and as the values for SCC at 2% was rated below average of the nine-point hedonic scale, this means that its physical appearance was not appealing to the panelists. This is postulated to have been the reason behind the low scores across the remaining parameters of the same treatment, as all of the values in flavor, tenderness and juiciness rated below average. Flavor values showed the SCN has a stong aroma which must have appealed to the consumers when used at low levels but as inclusion levels increased, its appeal to the panelists reduced as is reflected in the mean scores. Tenderness was least in SCC at 2% and highest (6.70) in SCA at 3%. This shows that at 3% level of inclusion, the SCA spice had a tenderizing effect on the *suya* as it was rated highest for tenderness by the sensory panelists.

Juiciness was least (4.63) in SCC at 2% level of inclusion and was highest (6.70) in SCN at 2%. In this study, at day four, there was a proportional relationship between flavor and juiciness thus supporting Aaslyng *et al.* (2002) report that juiciness facilitates chewing process as well as brings the flavour component in contact with taste buds.

5.15 Effects of interaction between treatments and varied inclusion levels on the organoleptic properties of *suya* on day seven sampling period

Interaction effect between treatments and inclusion levels on the organoleptic properties of *suya* on day seven (Table 4.15) showed values for color, flavour and overall acceptability to have not been significant indicating that all the treatments at their varied inclusion levels were acceptable and thus rated similar in those parameters to the sensory panelists. Safari *et al.* (2001) noted that tenderness, flavor amd juiciness are the most impotant contributing sensory attributes to eating quality. Values for tenderness was observed to increase across the sampling days and were in support of values reported by Naveen *et al.* (2016). Tenderness is the first and foremost quality that is sought in meat and this could have affected the acceptability of the *suya* to the sensory panelists. This occurrence could be postulated to have been as a result of aging and microbial attack, which could have led to weakening of the muscle tissues. Juiciness values shows SCA at 3% level of inclusion was better preffered by sensory panelists at day seven and could have been related to the low microbial load of the treatment on day seven, as SCC which was the least performing at all its varied inclusion level in organoleptic evaluation, had the highest microbial count on day seven.

On an overall, The least for all the parameters was the SCC at 2% inclusion level, this may have been because at such low levels, the SCC didn’t express itself fully to have appealed to the senses of the sensory panelists. SCN performed best majorly, probably due to its strong appealing flavor.

5.16 Effect of treatments and varied inclusion levels on the microbial properties of *suya* on days one, four and seven sampling period

All the means for the microbial properties of the *suya* for days one and four (Table 4.16) concurred with values reported by Osho (2004) and Inyang *et al.* (2005), and thus fell within the acceptable level of Standard Microbial load specification on animal food product of Wilson and Sperber (1991).

Initial values of TVBC, coliform count, total yeast count and total mold count were below log 6, which according to Aworh *et al.* (1998) in corresponding reports of Igene and Abulu (1984) proves that the *suya* was prepared in a sanitary environment. The meat kept for long because on day one (Table 4.16) values were quite low and this concurred with Lambert *et al.* (1991), James and James (2002) and Yang (2012) reports that initial bacterial load is extremely important to meat shelf life as holding other factors constant, lower initial bacteria counts are associated with longer shelf life of meat.

Total viable bacteria count on day one indicated that SCN had the least, while SCCgave the highest value and the reason for this could have been that the SCC didn't have any inhibitory effect on the bacteria isolated. For the day four, SCA was the least while the control was the highest and this was not surprising since the spices were expected to have had bactericidal and bacteriostatic effect on organisms isolated. However, for days one and four, its values though high, were within the acceptable grade of Standard Microbial load specification on animal foodproduct of Wilson and Sperber (1991). On day seven, except for SCA, values for the other treatments exceeded the acceptable grade and so microbial wise were unsatisfactory. This could have been the reason for the low means in proximate and organoleptic determination on day seven. SCA had the lowest TVBC and this reflected also in the pH values on same day, with SCA being the most acidic. Russell *et al.* (1996) reported that meat of alkaline nature will exhibit faster rate of microbial spoilage than that of an acidic nature. SCCTVBC count was the highest at day seven, and this observation concurred with reports of Lambert *et al.* (1991), James and James (2002) and Yang (2012) that initial bacterial load is extremely important to meat shelf life as it determines the overall shelf life of the meat product. It could be postulated that the poor performance of the SCC could have been as a result of the spice not being potent against the strains of micro-organisms isolated or the level at which the SCCwas included in the *suya* spice mix was not enough to have been potent against the types of bacteria present in the meat product. This postulation agrees with Zaika (1999) report that the antimicrobial activity of spices varies widely, depending on the type of spice or herb, test medium, and microorganisms. Inclusion level effect on microbial load of the *suya*, showed significant differences. At varied inclusion levels, on days one and four, there were no significant difference amongst the means as they all were statistically similar. However, on day seven, that included at 3% had the least TVBC value, while the other inclusion levels statistically ranked same.

Coliform counts on day one and day four showed no significant difference (P>0.05) amongst treatments. On day seven, SCA was the least in coliform counts and the SCN was the highest. It could be that the SCN on those sampling days lost potency against coliform bacteria being isolated. At varied inclusion levels, day one and day four showed no significant difference across means at all three levels on the *suya*samples. On day seven, however that included at 3% inclusion level ranked least microbially, the reason for this is not known as one would have expected that higher levels of inclusion would have performed best, but it agrees with reports of Eruteya and Odunfa (2009) who found 3% level of *suya* spice extracts to have been effective against some isolated microorganisms.

For the total yeast count, results gotten showed nothing detected on days one and four (Table 4.16) however, on day seven, counts were detected and they exceeded the acceptable grade for fungal counts of Standard Microbial load specification on animal foodproduct of Wilson and Sperber (1991), and this supported Taniwaki *et al.* (2001) reports of Fungi being slow growers in comparison to bacteria and seldom responsible for the spoilage of fresh proteinaceous material. This also supported the proximate values on day seven which showed high NFE values, as Taniwaki *et al.* (2001) also reported that fungal metabolism is best suited to substrates high in carbohydrates, whereas bacteria are more likely to spoil proteinaceous foods except for Lactobacilli. The highest value for the total yeast count on day seven was seen in SCC and the least was seen in SCA which had nothing detected. The reason for the SCChaving the highest yeast count could be that the amount in which it was included in the *suya* spice mix was not enough to have been inhibitory to the fungal organisms orSCC spice is not effective on fungal organisms. Zaika (1999), reported that although the antimicrobial activity of some spices and herbs is documented, the normal amounts added to foods for aroma is not enough to completely inhibit microbial growth. For inclusion level on day seven showed no significant difference in total yeast count across means.

Total mould count followed the same trend as total yeast count, likewise having nothing detected on days one and four. On day seven, the control ranked higher than the others in mould count thus performing worse, and that of SCA performed best, since it had no detected mould count. At varied inclusion levels, values across means were similar.

5.17 Interaction effect of treatments and varied inclusion levels on the microbial properties of *suya* on day one sampling period

Total viable bacteria count values was least in SCN at 3% and the highest was SCC at 4%. Values obtained were within the satisfactory range (<log4) of the Standard Microbial Load Specification on Animal Food Product of Wilson and Sperber (1991) and it reflected the hygienic measures that had been put in place to ensure minimal microbial contamination of the fresh meat up till the final product (*suya*), supporting similar reports by Osama and Gehan (2011). The SCC seemed to have had low inhibition on microbial activities as its microbial counts was high across its three levels of inclusion. So it could be postulated that the spice, SCC was not potent against strains of viable bacteria isolated or the inclusion levels was not sufficien to have been potent. Coliform count showed SCN at 2% to have

being the least and that of SCC at 3% being the highest, and the values were within that reported by Inyang *et al.* (2005) in their work on *suya*. Values were also satisfactory and reflected that irrespective of the treatment and their varied inclusion levels, all were safe for human consumption. No counts were detected on day one for total mould count and total yeast count.

5.18 Effect of interaction between treatments and varied inclusion levels on the microbial properties of *suya* on day four sampling period

Values for total viable bacteria count on day four though high, were still acceptable and were within values reported by Inyang *et al.* (2005). Values increased significantly from that obtained in day one and this was expected as lengthened storage duration has been reported by authors (Oyadeyi *et al.*, 2014; Daramola 2018) to increase microbial load in animal products. Means though significant across means, were especially low in that marinated with SCA at all three levels of inclusion and this goes to show that the SCA had a strong inhibitory effect on bacteria strains isolated and identified in the *suya*. Coliform counts were not significant across means of the treatments and their inclusion levels, while for total mould and total yeast counts, nothing was detected.

5.19 Effects of interaction between treatments and varied inclusion levels on the microbial properties of *suya* on day seven sampling period

Values for TVBC showed that asides those marinated with SCA, other treatments had mean values which exceeded the satisfactory level of the standard microbial load specification on animal food product of Wilson and Sperber (1991). This values indicated high microbial counts and resulted in the deterioration of the quality of the *suya*, which must have had an adverse effect on the sensory and proximate properties of the *suya*. SCC mean values were the highest across all the levels of inclusion and shows that it was the least effective in the preservation of the *suya* from microbial deterioration.

Coliform counts for SCA at 3% was the least and SCC at 2% was the highest. Asides those prepared with SCA, values for the other treatments at their inclusion levels, exceeded the satisfactory range of the standard microbial load specification on animal food product of Wilson and Sperber (1991). This values showed that at day seven, even though the product was rated above average in most of the organoleptic parameters, it had become unhealthy for human consumption microbial wise. Total yeast counts ranged between 3.54-4.72log with that marinated with SCN at 3% being the least and that marinated with SCC at 3% being the highest. However, no values were detected in *suya* marinated with SCA at all three levels of inclusion for total yeast counts.This values support Rusell (2001) report that odor and slime are not present in beef products until bacteria exceeded $1x10^8$cfu/cm or >log8. Total mould counts followed same trend as yeast counts, having zero counts in SCA across all three levels of inclusion. In the other treatments however, SCN at 3% was the least and that of the control was the highest. SCA is seen in this study to be very effective against fungal organisms.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

1. The control, followed closely by the Ashanti peppertreated samples performed best in relation to the physico-chemical properties of the *suya* judging by the crude protein, ash, pH and TBA value at day seven which was its longest sampling period. At varied inclusion levels, 4% was adjudged best, because of its low TBA values at sampling day seven.

2. Considering organoleptic properties, the least performing was the Cloves treated samples at all the levels of inclusion while the best was the Ashanti peppergroup, based on values obtained at day seven sampling period.

3. Three (3%) inclusion levels of Ashanti pepperin *suya*was found to be rated higher when compared with that of 2% and 4% in most of the parameters and treatments.

4. Ashanti pepper exerted the strongest antimicrobial action on the samples giving the longest shelf-life (seven days) of products stored at the ambient temperature while the poorest was observed with Cloves.

6.2 Recommendation

1. *Suya*coated with Ashanti peppercan be stored up to seven days compared with Clovesand *X. aetiopica*.

2. The best level of inclusion is 3% as the *Suya* rates best organoleptically and is safer to eat based on microbiological considerations.

3. Further research could be carried out on the inclusion level that would be best for Cloves to perform better organoleptically and microbially in *Suya* production.

4. Also, research into other spices that are locally available for use in intermediate meat products is also encouraged.

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APPENDIX 1

SENSORY ANALYSIS QUESTIONNAIRE

SENSORY EVALUATION PRELIMINARY TEST SHEET [QUESTIONNNIARE] USING NINE (9) POINT HEDONIC SCALE

NAME………………………………. GENDER…………………. PHONE NO …………………………….

Before you are coded samples, you are to test and critically observe each sample and give your inference in the appropriate format below for individual factors in the columns.

Please tick your level of preference for each palatability trait of the given sample

INDEX	**COLOUR**						**FLAVOUR**						**TENDERNESS**						**JUICENESS**						**ACCEPTABILITY**					
SAMPLES		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E		A	B	C	D	E
1	Extremely dark						Extremely bland						Extremely tough						Extremely dry						Dislike extremely					
2	Very dark						Very bland						Very tough						Very dry						Dislike very much					
3	Moderately dark						Moderately bland						Moderately tough						Moderately dry						Dislike moderately					
4	Slightly dark						Slightly bland						Slightly tough						Slightly dry						Dislike slightly					
5	Intermediate						Intermediate						Intermediate						Intermediate						Intermediate					
6	Slightly light						Slightly intense						Slightly tender						Slightly juicy						Like slightly					
7	Moderately light						Moderately intense						Moderately tender						Moderately juicy						Like moderately					
8	Very light						Very intense						Very tender						Very juicy						Like very much					
9	Extremely light						Extremely intense						Extremely tender						Extremely juicy						Like extremely					