EFFECT OF SOURCES OF LIQUID SMOKE ON THE QUALITY CHARACTERISTICS OFBROILER CHICKEN MEAT

BY

RAHMATULLAH YAQOOB
P17AGAN8012

DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADUBELLO UNIVERSITY,
ZARIA

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B.AGRICULTURE, AHMADU BELLO UNIVERSITY, ZARIA (2014)

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DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY,
ZARIA

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DECLARATION

I hereby declare that the work in this dissertation entitled **"Effect of Sources of Liquid Smoke on The Quality Attributes of Broiler Chicken Meat"** was carried out by me at the Animal Product Laboratory of the Department of Animal Science , Ahmadu Bello University, Zaria, under the supervision of Prof. M. Jibir and Prof. S. B Abdu. The information derived from literatures has been duly acknowledged in the text and list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

_______________ _______________ RAHMATULLAH YAQOOB
Signature Date
P17AGAN8012

CERTIFICATION

This dissertation titled "EFFECT OF SOURCES OF LIQUID SMOKE ON THE QUALITY ATRIBUTES OF BROILER CHICKEN MEAT" by Rahmatullah YAQOOB, meets the regulations governing the award of the degree of Masters of Science (M.sc) of the Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

______________________________ ______________________

Prof. M. Jibir Date
Chairman, supervisory committee
Department of Animal Science,
Faculty of Agriculture,
Ahmadu Bello University, Zaria.

______________________________ ______________________

Prof. S.B. Abdu Date
Member, supervisory committee,
Department of Animal Science,
Faculty of Agriculture,
Ahmadu Bello University, Zaria.

______________________________ ______________________

Prof. M. Kabir Date
Head of Department,
Department of Animal Science,
Faculty of Agriculture,
Ahmadu Bello University, Zaria.

______________________________ ______________________

Prof. Sani A. Abdullahi Date
Dean, School of Postgraduate Studies.
Ahmadu Bello University, Zaria.

DEDICATION

This work is dedicated to my youngest children, Aisha, Nuriyyah and Ummu-Sulaym for been so peaceful and promising during the cause of my study.

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ABSTRACT

This research was conducted to evaluate the antimicrobial properties of liquid smoke made from *Parkia biglabosa*, *Vitelleria paradoxa* and *Eucalyptus globulus* and their effect on the organoleptic properties of broiler chicken meat. The various liquid smoke produced were also analyzed for their yield and physico-chemical composition. The results of the qualitative analysis of the liquid smoke as indicated by Gass Chromatography and Mass Spectrometry (GCMS) analysis identified a total of 22, 18, and 15 chemical compounds in Liquid smoke parkia (LSP), Liquid smoke sheabutter (LSS) and Liquid smoke eucalyptus (LSE), respectively. The major components found across the liquid smokes produced included 2,4-Di-tert-butylphenol; 2,6 dimethoxy phenols; 3,5-dimethoxy-4-hydroxytoluene; 5-tert-butylpyrogallol and 2-Propanone, 1-(4-hydroxy-3-methoxyphenyl). The result revealed that There was significant ($P<0.05$) difference observed in the proximate composition of the grilled broiler chicken marinated in liquid smoke. The antibacterial effects were evaluated using the pour plate count method. There was no significant difference ($P>0.05$) for the total aerobic plate counts (TAPC). However, significant difference ($P<0.05$) was observed for total fungal count (TFC) with the highest counts recorded for liquid smoked meat sheabutter (LSMS-$1.6x10^2$)`while the least was recorded for Liquid smoked meat parkia (LSMP-$6.3x10^1$) and Liquid smoked meat eucalyptus (LSME-$3.3x10^1$). In all the storage periods, day 3 had the highest microbial count across all the parameters monitored having the highest count of $7.1x10^4$ for TAPC followed by day 1 ($8.25x10^2$) and day 7 ($2.17x10^3$) whose values were statistically similar. The microbial count obtained from this study fell within the acceptable range (10^6-<10^7) specified by the International Commission of Microbial Specifications on Foods and also lower than NAFDAC's specification ($5.0x10^5$ - $1.0x10^6$), thus it is fit for human consumption. The sensory parameters such as colour, flavour, aroma, tenderness, juiciness, overall acceptability and ranking showed significant differences ($P<0.05$) across the treatments with the mean values for LSMP having the overall best score followed by LSMS and the least score was in LSME. There was significant difference ($P<0.05$) in the liquid smoke treatments with respect to their sensory qualities and overall acceptability throughout the three different storage periods. There was also reduction in the sensory scores as the storage period increased. However, it was observed generally that all the sensory scores fell above average on the 5 point Hedonic scale. From the findings of this research, it can be concluded that Liquid smoke from Parkia, Sheabutter and Eucalyptus wood can effectively be used as a natural smoke flavouring and an alternative preservative to broiler chicken meat.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Meat is highly susceptible to spoilage due to its chemical and enzymatic activities which leads to the breaking down of fat, protein, and carbohydrate of the meat, resulting into the development of off-odour, off-flavour and slime formation there by rendering it objectionable for human consumption(Mahendra and Mridula, 2018). Spoilage processes can be controlled or curtailed by using different preservation procedures such as; reducing the temperature by chilling or freezing, heating, use of chemicals, salting, drying in wind or sun, or by smoking. These processes are carried out to inactivate or destroy the microbes. Meat has originally been processed to preserve it, and the process of various methods of preservations have been found to cause so many changes in its texture, flavour and even its colour, hence are also used as a means of adding variety to the diet (FOA, 2014).

Smoking is a centuries-old food preservation process. It has been used for some years as preservatives and aromatizers of meat and fish (Schindler, 1997).Wood smoke contains antimicrobial compounds that preserves meat products and is used to impart flavour and colour. These antimicrobial, colour and flavourproperties of wood smoke are due to the presence of phenolic and carbonylic compounds naturally present in wood (Holley and Patel, 2005). The preservative action of the smoking process for foods depends upon factors such as processing temperature and partial dehydration. The conventional smoking process has been continuously substituted by the use of smoke flavourings like liquid smoke (Guillen and Ibargoitia, 1998)

Liquid smoke is a high browning condensable liquid of pyrolized wood chips or sawdust which has the capability to impart characteristic smoke flavour and colour to a food product (Gary, 1992). Liquid smoke extracts are being used to replace the traditional smoking system in most part of the world in processing varieties of meat product. One of such product is smoked chicken. Liquid smokes are known to possess antioxidant properties, and serve as natural alternatives to conventional antimicrobials (VanLoo *et al.*, 2012). It has been demonstrated that commercial liquid smoke preparation are effective against various types of spoilage and pathogenic microorganisms (Milly *et al*., 2005). It exhibit antimicrobial activity against *Listeria, Escherichia coli, Staphylococcus aureus,* and *Staphylicocal enterotoxins* which are the main contaminants of meat products (Lingbeck *et al*., 2014).

Liquid smoke presents better alternatives as it provide a higher uniformity of flavour and colour without the inconvenience of wood or sawdust handling or smokehouse clean up. Also, the emission problems of traditional smoking have been eliminated since tar and resins are removed from the natural smoke by filtration, distillation, and aging (Gonulalan *et al*., 2003 and Simko, 2002). Also, considerable decrease in processing time, lowered environmental pollution and improved hygiene are among the advantages of such technology (Guilien, *et al*., 2000; Stolyhwo and Sirkorski, 2005)

Nowadays, smoke flavourings of different composition are available in developed countries and can be combined to obtain products with different organoleptic characteristics (Simko, 2002). Different wood types can be used to produce liquid smoke depending on the flavour you are driving at and the availability of the wood type, some wood smoke flavour may be bitter or intense while some are sweet and mild (Ojeda *et al*. 2002). The chemical composition of liquid smoke depends primarily on the wood type (soft or hard) and moisture content of wood, the latter influences the pyrolysis temperature and duration of smoke generation (Guillen and Ibargoitia, 1991; Cadwallader, 2007).

1.2 Problem Statement

Liquid smoke can be produced from different wood species that have been used either singly or in combination for traditional smoking in Nigeria.Several authors have established the fact that liquid smoke offers several advantages over traditional smoking. Such advantages includes better control, wider applications to food variety, superior product homogeneity, easiness to store, less time and labour as well as environmental friendliness (Verlet *et al*., 2010).However,there is no specific information available concerning the effects of wood varieties (like Parkia wood, Sheabutter wood and Eucalyptus wood) used in making the liquid smoke on the organoleptic quality and shelf stability when applied to broiler chicken meat. Hence, the need for thisstudy.

1.3 Justification of the Study

The demand for meat in Nigeria with respect to income, nutrition awareness, and better flavour is increasing. The concern for the quality of meat consumed is also increasing due to the growing concern on health. The main problem to the consumption of locally processed smoked meat product lies with the poor sanitary conditions associated with production handling and processing. High bacterial countsfound in meat product arethe results of poor hygiene and handling practices employed (Zahraddeen *et al*., 2007)

Studies have been carried out on the antimicrobial activity (Indiarto*et al.*, 2019), antioxidant effects (Kjallstran and Peterson, 2001), and influence on organoleptic properties (Martinez *et al*., 2007) of smoke flavourings (liquid smoke).It is viable for use on marinades, sauces, brines and typically on processed meats such as smoked chicken due to the concentration of the smoke flavour. In addition, liquid smoke condensate is categorized as an all-natural antimicrobial in food preservation (Lingbeck *et al*., 2014). Being an all-natural antimicrobial in food, it may also appeal to many consumers who tends to have concerns on food preserved using synthetic additives. Therefore, this research would be valuable for the industries and research communities in the food science and technology as it would aid in producing a more uniform shelf stable meat products that can be stored under ambient temperature, eliminating the limitations of environmental pollution and the traditional livestock product marketing system.

1.4 Objectives of Study

The broad objective of this research was to compare broiler chicken meat marinated in liquid smoke made from *Parkia biglobosa* (Parkia), *Vitelleria paradoxa* (Sheabutter) *and Eucalyptus globules* (Eucalyptus) woodfor their sensory characteristics and shelf stability. The specific objectives of this study were to:-

i. Determine the physical and phytochemical properties of liquid smoke made from three different commonly used woods (*Parkia biglobosa Vitelleria paradoxa and Eucalyptus globulus*)species.

ii. Evaluate the Organoleptic properties of grilled broiler chicken meat marinated in the three different liquid smoke produced from *Parkia biglobosa, Vitelleria paradoxa and Eucalyptus globulus* wood as influenced by storage periods.

iii. Evaluates (shelf stability) of grilled broiler chicken meat marinated in the three different liquid smoke produced from *Parkia biglobosa, Vitelleria paradoxa and Eucalyptus globulus* wood specie.

1.5 Hypotheses

Ho- There is no difference in the quality of the liquid smoke produced from the three different wood varieties (*Parkia biglobosa, Vitelleria paradoxa and Eucalyptus globulus*).

Ho- There is no difference in the organoleptic properties of the grilled broiler chicken meat marinated in the three different liquid smoke produced from the three different wood types.

Ho- The storage periods has no effect on organoleptic properties of the grilled liquid smoked chicken meat made from three different wood species

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Meat

Meat is defined generally as any edible animal flesh, it is considered as an excellent source of high value biological protein containing all the amino acids necessary for body functions and minerals like; zinc, iron, magnesium, selenium, phosphorus and vitamins (Mahendra and Mridula, 2018). There are three main categories of meat namely; Red meat (these are beef, mutton, chevon, etc), poultry (commonly referred to as white meat, these includes; chicken, turkey, rabbits, etc) and sea food which includes fish, shellfish etc, (*https://www.master class.com*)

2.2 Nutrient Profile of Meat

Meat ranks one among the most significant, nutritious and favored food item available to man It is composed of water, protein and amino acids, minerals, fats, vitamins and other bioactive components, and small quantities of carbohydrates (FOA,2020). The nutrient composition of meat varies widely with the species, quality and part of the meat. Poultry meat are highly nutritious, tasteful, easy to prepare and appropriate for different food combinations (Leskanich and Nobel, 1997). Chicken meat has no fiber but has protein, lipids, ash, and carbohydrates and energy with the proximate composition of 74.4, 22.6, 1.47, 1.15 and 406.7 Metabolizable Energy (ME) respectively (Nkukwana *et al*., 2014).

2.3 Shelf Life and Spoilage of Meat

The shelf-life of meat and meat products is the period of time during which storage is possible and food retains its quality characteristics until the onset of spoilage phenomena. The shelf-life of products is strongly linked to their deterioration, creating a borderline between an acceptable and an unacceptable bacterial concentration, which determines off-odours, off-flavours and an undesirable appearance. These sensorial modifications are related to the number and types of microorganisms initially present and their subsequent growth (Maria *et al*., 2015) For meat products, the starting total microbiota is approximately 10^2-10^3 cfu/g, consisting of a huge variety of species (Ray and Bhunia, 2013)

Meat is considered to be spoiled when it is unfit for human consumption. Meat is highly susceptible to spoilage due to its chemical and enzymatic activities which leads to the breaking down of fat, protein, and carbohydrate in the meat, resulting into the development of off-odour, off-flavour and slime formation there by rendering it objectionable for human consumption (Mahendra and Mridula, 2018). Generally spoilage occurs when the microbial populations reaches around 100million per cm^2 (Mathew and Jaganathan, 2017). There are three major mechanisms for meat and meat products spoilage after slaughtering, during processing and storage, these are; microbial spoilage, lipid oxidation and autolytic enzymatic spoilage. Understanding of the intrinsic factors and extrinsic factors at every meat processing stage (i.e from the pre-slaughtering to processing to meat product) is necessary before developing proper handling, pretreatment and preservation techniques for meat.

2.3.1 Microbial spoilage

Microbial spoilage is caused by the 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 (Wikipedia, 2020). Meat and meat products provides an excellent growth media for a variety of microflora (bacteria, yeasts and molds) some of which are pathogenic (Jay *et al*., 2005). The environmental conditions of the meat during the different steps of its production and trade create a specific ecological niche, which favors some microbial strains initially present in the meat or introduced by cross contamination, (Castellano *et al*., 2008; Nychas *et al*.,2008).

The composition of micro flora in meat depends on various factors such as; husbandry practices (free range or intensive rearing), age of the animal at the time of slaughtering, handling during temperature controls after processing and during distribution, preservation methods, type of packaging and handling and storage by consumer (Cerveny *et al*., 2009). The most common type of bacteria found in meat before spoilage are*Staphylococcus, Bacillus, Campylobacter, Clostridium, Listeria, Salmonella, Escherichia coli,* etc. Mold species found in meat include *Cladosporium, Geotrichum, Penicillium and Mucor* while yeasts species include *Candida spp and Cryptococcus spp* (Dave and Ghaly, 2011). The storage conditions affect the type of microbes found in meat and meat products (Carveny *et. al.*, 2009). The favorable pH for the growth of spoilage bacteria for meat is in the range of 5.5-7.0, hence, slime formation, structural degradation of the meat, off odors and appearance changes when such bacterias are found in meat within this pH range (Russell *et al*., 1996).

2.3.2 Lipid oxidation of meat

Autoxidation of lipids is a natural processes which affects the fatty acids of meat and lead to its oxidative deterioration and off-flavours development (Simitzis and Deligeorgis, 2010). After slaughtering of animals, the fatty acids in tissues undergo oxidation when the blood circulation stops and metabolic processes are blocked (Linares *et al.*, 2007). Oxidation of lipids in meat depends on several factor, such as; fatty acid composition, the level of the antioxidant vitamin E and pro oxidants such as the free iron presence in muscles. Poly saturated fatty acids are more susceptible to lipid oxidation. Hydro peroxides are produced due to the lipid oxidation of highly unsaturated fatty acid fractions of membrane phospholipids, which are susceptible to further oxidation/ decomposition (Enser, 2001). Their breakage produce oxygenated compounds such as aldehydes and ketones. These secondary products can cause loss of colour and nutritive value due to sever effects on lipids, pigments, proteins, carbohydrates and vitamins (Simitzis and Deligeorgis, 2010). In meat, lipid hydrolysis can take place enzymatically or non-enzymatically. The enzymatic hydrolysis of fats is termed lipolysis or fat decomposition and is governed by specific enzymes such as lipases, esterase and phospholipase. Lipolytic enzymes could either be endogenous of the food product (such as milk) or derived from psychotropic microorganisms (Ghaly *et al*., 2010).

2.3.3 Autolytic Enzymatic Spoilage of Meat

Enzymatic actions are natural processes that take place in the muscle cells of the animals after they have been slaughtered and are the leading cause of meat deterioration. The enzymes have the ability to combine chemically with other compounds and work as catalysts for chemical reactions which finally end up in meat spoilage. During the autolysis, the complex compounds (carbohydrates, fats and protein) of the tissues are broken down into simpler ones resulting in softening and greenish discolouration of the meat. These autolysic changes include proteolysis and fat hydrolysis which are precursors for microbial decomposition. Excessive autolysis is termed "souring. Postmortem breakdown of polypeptides are the result of tissue proteases and is responsible for flavour and textural changes in meat (Toldra and Flores, 2000). The enzymes calpains, cathepsins and amino peptidases are found to be responsible for post mortem autolysis of meat through digestion of the Z- line proteins of the myofibril (O'Halloran *etal*., 1997).

2.4 Preservation Methods of Meat

The process of various methods of preservations have been found to cause so many changes in its texture, flavour and even its colour, hence are also used as a means of adding variety to the diet (FOA, 2014). The aims of meat preservation methods are to inhibit the microbial growth and to minimize the oxidation and enzymatic spoilage (Dave and Ghaly, 2011). Fresh Meat because of their high nutritional value and presence of easily usable carbohydrates, fat and protein, provides an ideal environment for spoilage microbes (Uzeh *et al*, 2006). Microbial spoilage results in a sour taste, off-flavours, discolouration, gas production, pH change, slime formation, structural components degradation, offodors and change in appearance. Preservation ensures that the quality, nutritive value and edibility of meat remain intact (Pal and Devrani, 2018).

To prevent this spoilage, meat is usually processed into products using many processing techniques such as intermediate moisture processing methods.Many meat delicacies are available in Nigerian markets today, but the high ambient temperature and humidity coupled with poor handling practices predisposes such meat products to massive microbial contamination and rapid deterioration. Meat is generally regarded as one of the most popular nutritious items of human diet. Nigeria and most tropical countries are said to have a large market in smoked meat product which are a significant source of high quality dietary animal protein available to both the urban and the rural population (Okonkwo *et al.*, 1994)

2.4.1 Refrigeration

Refrigeration also known as chilling is the most widely used method of preservation for short term storage of meat as it slows or limits the rate of spoilage (Cassens ,1994), Storage of fresh meat is done at a refrigeration temperature of 2 to 5°C. Chilling is critical for meat hygiene, safety, shelf life, appearance and nutritional quality (Zhou, Xu and Liu, 2010). Carcasses are first hanged in chilled coolers (15°C) to remove their body heat, and are then passed on to holding coolers (5°C). It is essential to maintain proper spacing between carcasses so as to allow proper air circulation. Refrigeration of meat begins with the chilling of animal carcass and continues throughout the entire channels of holding, cutting, transportation, retail, display and even in the customer household before the ultimate use. The relative humidity is generally kept at 90% in order to avoid excessive shrinkage due to loss of moisture. The storage life of a refrigerated meat is influenced by species of origin, initial microbial load, packaging and temperature as well as humidity. Poultry meat starts with comparatively high microbial load. Irrespective of species of origin, maximum care should be taken during handling of meat in order to check further microbial contamination (Pal and Devrani, 2018). Refrigerated temperature favors the growth of psychrophilic organisms causing spoilage of meat in the course of time. Generally, fresh meat remains in good condition for a period of 5-7 days if kept at refrigerated temperature of 4 ± 1°C (Carroll and Alvarado, 2008). Cold-shortening and toughening may result from ultra-rapid chilling of pre-rigor meat (Ockerman and Basu, 2004). It is emphasized that the processed meat should be stored under refrigerated condition till they are finally consumed.

2.4.2 Freezing

Freezing is an ideal method of keeping the original characteristics of fresh meat. Meat contains about 50-75% water by weight, depending on the species, and the process of freezing converts most of water into ice (Heinz and Hautzinger, 2007). It stops the microbial load and retards the action of enzymes. The most significant advantage of freezing is the retention of most of the nutritive value of meat during storage, with a very little loss of nutrients occurring due to drip loss during thawing process. It is important to pack fresh meat in suitable packaging film before freezing to prevent the meat from undergoing freeze burn, this abnormal condition occurs due to progressive surface dehydration resulting in the concentration of meat pigments on the surface.

Microbial growth stops at 12°C and total inhibition of the cellular metabolism in animal tissues occurs below 18°C (Perez-Chabela and Mateo-Oyague,(2004). However, enzymatic reactions, oxidative rancidity and ice crystallization will still play an important part in spoilage (Zhou, Xu and Liu 2010). During freezing, about 60% of the viable microbial population dies but the remaining population gradually increases during frozen storage (Dave and Ghaly, 2011). The quality of frozen meat is influenced by its freezing rate either fast or slow, Fast freezing produces a better quality meat than slow freezing. In slow freezing, there is formation of large ice crystals, which may cause physical damage to muscular tissue, giving it distorted appearance in the frozen state (Dave and Ghaly, 2011)

2.4.3 Curing

Sodium chloride, sodium nitrate, sodium nitrite and sugar are the main curing ingredients. Various methods of curing are practiced, these includes; dry cure, pickle cure, injection cure, direct cure etc. Preservation of meat by heavy salting is an old age practice. Sodium chloride has a long history of use in food preservation in sufficiently high concentrations. It was applied as a thumb rule because refrigeration facilities were not available during olden days. Later, curing by common salt and sodium nitrate resulted in comparatively improved products. Sodium Chloride inhibits microbial growth by increasing osmotic pressure as well as decreasing the water activity in the micro-environment (Dave and Ghaly, 2011). Some bacteria can be inhibited by concentrations as low as 2% (Urbain ,1971). A concentration of 20% of sodium chloride is high enough to inhibit many food spoilage yeasts including *Debaryomyces hansenii, Yarrowia lipolytica, Kloeckera apiculata, Kluyveromyces marxianus, Pichia anomala, Pichia membranaefaciens, Saccharomyces cerevisiae, Yarrowia lipolytica, Zygosaccharomyces bailii, and Zygosaccharomyces rouxii* (Fleet, 1999). However, some microorganisms from the genera

Bacillus and Micrococcus have shown ability to tolerate high concentrations of salt (Urbain, 1971). Sugars have the capabilities to bind with moisture and reduce water activity in foods (Dave and Ghaly, 2011). Dextrose, sucrose, brown sugar, corn syrup, lactose, honey, molasses, maltodextrins, and starches are generally used in dried meat processing as a source of sugars or carbohydrates to enhance flavour, reduce harshness of salt and lower water activity (USDA, 2005).

2.4.4 Thermal processing

Thermal processing as a preservative method is employed to eliminate the spoilage causing microorganisms (Safefood 360, Inc. 2014). There are two main temperature categories employed in thermal processing: Pasteurization and Sterilisation. Pasteurization refers to moderate heating in the temperature range of 58-75°C, which is also the cooking temperature range of most of the processed meats. Heat treatment extends the shelf life of meat significantly. It is imperative that such products also need to be stored under refrigerated conditions (Fellows, 2017). Sterilization refers to the severe heating of meat at the temperatures above 100°C whereby all spoilage causing microbes in meat are killed or their microbial cells are damaged beyond repair (Pal, 2014).

2.4.5 Canning

Canning is the most efficient meat preservation method, It involves the process of preservation achieved by thermal sterilization of a product held in sealed containers (Guerrero-Legarreta 2014). Canning preserves the sensory attribute such as appearance, flavour and texture of the meat products to a large extent. Besides, canned meat products have a shelf life of at least two years at ambient temperature. Canning involves several steps, which include preparation of meat, precooking, filling, exhausting, seaming, thermal processing, cooling, and storage (Pal and Devrani 2018).

2.4.6 Dehydration

Dehydration is the removal of water from meat making them unavailable to the microorganisms. The extent of unavailability of water to microbial cell is expressed as water activity. Dehydration lowers the water activity considerably to prevent the growth of spoilage causing microbes (Pal, 2014). Sun drying of meat chunks as a means of preservation was practiced in ancient days but rehydration of such meat chunks used to be limited. The mechanical drying process involves the passage of hot air with controlled humidity but here also there is difficulty in rehydration(Pal and Devrani, 2018).

2.4.7 Freeze drying

This is a satisfactory process of dehydration, preservation due to better reconstitution properties, nutritive quality and acceptability of the meat products. Freeze drying involves the removal of water from a food by sublimation from the frozen state to vapor state by keeping it under vacuum and giving a low heat treatment (Pal, 2014).Freeze drying of meat is carried out in three steps, namely pre-freezing, primary drying and secondary drying (Fellows, 2017). Meat is first frozen at -40°C, and then it is dried under vacuum for 9-12 hours at low temperature in plate heat exchangers at 1-1.5 mm pressure of Hg. Ice crystals get sublimed to water vapors and there is no rise of temperature. In the 1st phase of drying, free and immobilized water of meat, which is freezable and constitutes about 90-95% of total moisture, is removed. Secondary drying is done at high temperature to remove remaining 4-8% bound water. Freeze dried products are packed under vacuum and have very good storage stability (Pal and Devrani, 2018).

2.4.8 Irradiation

Irradiation is also defined as cold sterilization". It is the emission and propagation of energy in the material media. The electromagnetic radiations are in the form of continuous waves that are capable of ionizing molecules in their path, these radiations can destroy the microorganisms by fragmenting their DNA molecules and causing the ionization of water within microorganismsDave and Ghaly (2011). It is important to mention that microbial destruction of foods take place without significantly rising the temperature of the food (Pal and Devrani, 2018). Gamma radiations produces desired effect only during food irradiation, these are widely used in food preservation. Among the known ionizing radiations, UV radiations are mostly bactericidal in nature but do not have good preventing power, so these are used only for surface sterilization of meat (Pal, 2014).

2.4.9 Smoking

Smoking is a centuries-old food preservation technology which is still frequently used nowadays. It have been used for some years as preservatives and aromatizers of meat and fish (Schindler, 1997). Smoking adds desirable sensory properties to many foods products,   as much as 40-60% of the total amounts of meat products are smoked (Sikorski, 2016). It is now well known that smoke contains a large number of wood degradation products such as aldehydes, ketones, organic acids, phenols and many more which are mostly antioxidants and antimicrobials(Toledo, 2008). Preservation of meat by smoke is also due to surface dehydration, lowering of the surface pH and antioxidant property of smoke constituents. Curing and smoking of meat are closely related. These days, curing is usually followed by smoking. Smoke is produced in specially constructed smoke house where sawdust or hard wood and sometimes both are subjected to combustion at the temperature of about 300°C (Pal and Devrani, 2014). The preservative action of the smoking process for foods depends upon factors such as processing temperature and partial dehydration. But however, the conventional smoking process has been continuously substituted by the use of smoke flavourings like liquid smoke (Guillen and Ibargoitia, 1998). Smoke generation is accompanied by formation of numerous organic compounds and their condensation products. Aldehydes and phenols condense which constitute 50% of smoke components and contributes to the colour of the smoked meat products. Phenols act mainly as the chief bactericidal compounds. Currently, many liquid smoke preparations are commercially available in the developed countries. Liquid smoke is generally prepared from hard wood where the polycyclic-hydrocarbons are removed by filtration and fractionalization. Application of liquid smoke on the product surface before cooking imparts a smoky flavour, which is very much liked by consumers, (Pal, 2014). This research would dwell more on liquid smoking as a preservative method and flavour enhancer.

2.9 Smoking methods

There are two major types of smoking methods depending on the amount of heat applied;these are cold smoking and hot smoking.

2.9.1 Cold smoking

Cold smoking differs from hot smoking in that the food remains raw, rather than cooked, throughout the smoking process (*hotsmoked.co.uk*). Smokehouse temperatures for cold smoking are typically done between 20 to 30 °C(Myrvold, 2011). In this temperature range, food take on a smoked flavour, but remain relatively moist and raw. Cold smoking does not cook food, and as such, meat should be fully cured before cold smoking(Myrvold, 2011).The length of smoking process for cold-smoked product is much longer that for hot smoked product, but a pasteurization temperature is not reached in any stage of the process. (Vaz-Velho, 2003). Cold smoking can be used as a flavour enhancer for items such as cheese or nuts, along with meats and sea food products. Cold smoking, or any other type of smoking where the core temperature of the food product is below 50^0C for a significant amount of time will have residual micro flora than those hot smoked product where the high internal temperature is reached. Therefore the temperature and times used in processing cold smoked products are highly favorable for the invasion of food spoilage microorganisms (Vaz-Velho, 2003)

2.9.2 Hot smoking

Hot smoking exposes the foods to smoke and heat in a controlled environment such as a smoker oven or smokehouse. Hot smoking requires the use of a smoker which generates heat either from a charcoal, electric or gas based heating element within the smoker or from a stove-top or oven, a food product is hot smoked by cooking and flavoured with wood smoke simultaneously *(hotsmoked.co.uk.).* They are typically safe to eat without further cooking. Hot smoking is executed within the temperature range of 52 to 80 °C.(Myrvold, 2011). When food products are smoked within this temperature range, foods are fully cooked, moist, and flavourful. If the smoker is allowed to get hotter than 85 °C, the foods will shrink excessively, buckle, or even split. Smoking at high temperatures also reduces yield, as both moisture and fat are cooked away. The temperature attained during hot smoking is efficient in killing the vegetative microorganisms but not all spores, hence the most probable spoilage agent will be spore forming microorganisms or post smoking contaminants (Vaz-Velho, 2003).

2.10 Types of WoodsUsed in Smoking Meat

Different wood types can be used for smoking depending on the flavour you are driving at and the availability of the wood type, some wood smoke flavour may be bitter or intense while some are sweet and mild (Guillen and Ibargoitia, 1991; Cadwallader, 2007).Thus, smoke could be generated from hickory, oak, wild cherry, apple wood, maple, bamboo, mangrove eucalyptus (Yang *et al*., 2016), sheabutter, parkia wood, etc. The choice of wood is influenced by its availability and the type of flavour you are aiming at. Recent trend in the smoke flavour industry is to produce liquid smoke as a byproduct of the process of making briquetted charcoal for backyard barbecues (Toledo, 2008). In Nigeria, road side meat vendors use different types of wood for smoking their meat product (*suya*,*tsire*, *balangu*, etc) either singly or in combination. Soft Wood trees that are sappy are not suitable for smoking meat as they hold significant quantities of resin, which produces a harsh-tasting soot when burned.

2.10.1 Parkia tree (*Parkia biglobosa*)

Commonly known as African Locust Bean (English) or Dorawa (in hausa), is a multipurpose medium sized tree legume found in many African countries. It reaches 20-30 m high. It has a dense, widely spreading umbrella-shaped crown and a cylindrical trunk that can reach 130 cm in diameter, frequently branching low. The bark has longitudinal cracks, scaly between the cracks and thick, It is ash-grey to greyish-brown in colour. It exudes an amber gum when cut. The leaves are alternate and bipinnate, 30-40 cm long, bearing up to 17 pairs of pinnae (Sina *et al*., 2002). The seeds, the fruit pulp and the leaves are used to prepare numerous foods and drinks, and also used in livestock and poultry feed (Orwa *et al*., 2009; Sina *et al*., 2002; Hopkins, 1983). The wood is used in light constructions, poles, mortars, and many other kinds of furniture and utensils. It is valuable firewood and provides pulp to make paper. The bark is used traditionaly in ethnomedicine. A root decoction is reported to treat coccidiosis in poultry. Green pods are used as fish poison to catch fish in rivers. African locust bean trees are used as ornamental. They are useful soil improvers and their leaves provide green manure (Sina *et al*., 2002).

2.10.2 Sheabutter Tree (*Vitellaria paradoxa*)

Commonly known as Sheabutter or Sheanut (English), Kadanya (Hausa),is a deciduous, small to medium-sized tree growing up to a height of 15-25 m. Leaves are caduceus and spirally arranged, mostly in dense clusters at the tips of branches. Fruit is a 1 or 2-seeded ellipsoid berry (4-8 cm), weighing 10-50g. The Shea tree is indigenous to African savannahs from Senegal to Sudan, Western Ethiopia and Uganda. It can also be found in Nigeria, Cameroon, the Central African Republic, Ghana, Guinea and Congo.It can grow on a variety of soils (Heuzé andTran, 2015).

2.9.3 Eucalyptus Tree (*Eucalyptus globulus*)

Also known as Blue Gum and Eucalyptus (English) or Turare (Hausa) is a large evergreen tree with a narrow crown that becomes rounded for trees growing in the open; it usually grows up to 55 to 70m. The straight, cylindrical bole can be up to 200cm in diameter (*http://www.prota.org*). It is an important source of fuel wood in many countries. It burns freely, leaves little ash, and produces good charcoal. Plantations can be harvested for firewood every 7 years. It is also widely used as pulpwood (Skolmen, 1983). The wood is unsuitable for lumber because of excessive cracking, shrinkage, and collapse on drying, but is used for fence posts, poles, and crates (Skolmen and Ledig, 1990).

2.11 Wood Smoke

Wood smoke is an aerosol produced during pyrolysis of wood at elevated temperatures and reduced oxygen. Wood smoke consists of three phases namely; compounds in the gaseous phase, particles of liquid droplets, and solids. When condensed and given enough time for the polymerized components to settle out, the liquid fraction is called **liquid smoke**. There are over 400 compounds identified in wood smoke or smoke flavour from a number of sources. So far, 40 acids, 22 alcohols, 131 carbonyls, 22 esters, 46 furans, 16 lactones, and 75 phenols have been identified Maga 1987. The origin of the compounds in wood smoke is the polymers in the wood and the heat-induced chemical reaction between the heated polymers, gasified intermediates, and moisture. Hence, the composition of wood smoke will vary with the type of wood used in producing the smoke and the temperature and moisture content of the wood. Wood smoke performs several functional roles in food. Whether it is applied as a gas from smoldering wood chunks or chips or as liquid smoke, which is considered a natural flavour (Toledo, 2008). Wood smoke contains antimicrobial compounds and has been used to impart flavour and colour and to preserve meats. The antimicrobial properties, colour andflavour of wood smoke are due to the presence of phenolic and carbonylic compounds naturally present in wood (Holley and Patel, 2005).

2.11.1 Types of wood smoke

There are two major types of wood smoke; the traditional wood smoke and the natural smoke condensate. The traditional wood smoke is generated from the burning of hardwoods, hardwood dust, corn cobs, mesquite, etc. The vaporous and condensed smoke phases are transferred to the smokehouse and meat products directly while, natural smoke condensate are methods of smoking that are more technologically advanced relying on improved smoke generation technology and application advantages (Milly, 2003). They are smoke that has been cooled and condensed to form liquid smoke, a process identical to that of traditional smoke being applied to a meat product.

2.12 Smoke Flavourings

According to the International Organization of the Flavour Industry,Smoke flavourings is a complex mixtures of components of smoke obtained by heating untreated wood to pyrolysis by a limited and controlled amount of air, dry distillation or superheated steam, then collecting the wood smoke in an aqueous collection system (IOFI, 2012). Nowadays, smoke flavourings of different composition are available in developed countries and can be combined to obtain products with different organoleptic characteristics (Simko, 2002). A number of wood smoke preparations are now used in the industry as a flavour. Smoke flavour is GRAS (i.e Generally Regarded As Safe) and is considered by both the United States Department of Agriculture (USDA) andFood and Drug Administration (FDA) as a natural flavor (Milly, 2003). The Knowledge of the smoke composition has helped the food industry to produce smoke preparations with different flavour and functional properties. Since flavour is a result of the interactions among the various compounds in smoke, treatments that remove certain smoke components may be used to alter the flavour of smoke (Toledo, 2008). There are two major types of smoke favors, namely; powdered smoke and liquid smoke.

2.12.1 Powdered smoke

Also known as liquid smoke powder is the solid form of liquid smoke where a carrier material is used to trap the active compounds of the liquid smoke (Toledo, 2008).This is achieved though spray drying technology. The material used as a carrier usually has high solubility capability, examples of such carriers used are, maltodextrin, gum Arabic, spices and salt, also known as "smoke flavoured salt" (Maryam, 2015)

2.12.2 Liquid smoke

Also termed as condensed smoke , wood vinegar, pyroligneous acid (Yang *et al*, 2016), is a high browning condensable liquids of pyrolized wood chips or sawdust which has the capability to flavour and impart characteristic smoke colour to food products (Gary, 1992). Liquid smoke extracts have been in use as a flavouring agent in the developed countries, they are known to possess antioxidant properties, and serve as natural alternatives to conventional antimicrobials (VanLoo *et al.*, 2012). The carbonization of many different types of wood can be used to produce various wood vinegars including Eucalyptus,oak, bamboo, mangrove, coconut shell, and apple trees. (Yang *et al*, 2016). Liquid smokes, either full-strength or refined, offer several advantages over wood smoke, such as better control of PAH content, wider diversity of applications to food systems, superior product homogeneity, easiness to store and less environmental pollution (Varlet *et al*. 2010).

2.13 Antioxidant and Antimicrobial Properties of Liquid Smoke

The antimicrobial properties of smoke condensates have traditionally been accredited to the phenolic components. The minimum inhibitory concentration (MIC) of the various smoke fractions indicate that high carbonyl levels and low pH, high titreatable acidity combine to make a smoke fraction highly effective as a microbial growth inhibitor (Milly, 2003). Several authors have studied the antimicrobial activity (MacRae, Hudson and Towers, 1989), antioxidant effects (Kjallstran and Peterson, 2001), and its influence on organoleptic properties (Martinez, Salmeron, Guillen and Casas, 2007) of smoke flavourings.

It has been demonstrated that commercial liquid smoke preparation are effective against various types of spoilage and pathogenic microorganisms (Milly *et al*. 2005). It exhibit antimicrobial activity against *Listeria*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylicocal enterotoxins* which are the main contaminants of meat products (Lingbeck *et al*., 2014). Milly (2003), also reported that Utilizing liquid smoke in processing RTE (Ready To Eat) meat products offers the processor a means of guaranteeing product safety and complying with rules addressing environmental contamination from Listeria monocytogenes.

2.14 Physicochemical Properties of Liquid Smoke

Gas chromatography mass spectroscopy (GC-MS), a sensitive hyphenated system, iswidely used to analyze, identify, and quantify the chemical compositions of natural products. The unknown chemical composition of liquid smoke from different plants can be determined by matching the peak mass spectra distribution of the samples or unknown with the NIST library MS database (Chan *et al*. 2012).

The physicochemical composition of liquid smoke depends primarily on the wood type and moisture content of wood, the latter influences the pyrolysis temperature and duration of smoke generation (Guillen and Ibargoitia 1991; Cadwallader 2007). A majority of the dry mass of wood is composed of cellulose, hemicelluloses and lignin. The thermal decomposition of cellulose produces anhydroglucose, carbonyl-containing compounds and furans (Montazeri *et al*., 2013) Hemicellulose decomposition is similar to cellulose decomposition, but yields acetic acid and carbon dioxide. Partial pyrolysis of lignin produces various types of phenolic compounds (Miler and Sikorski 1990). Therefore, the thermal degradation of wood results in a complex mixture of compounds, which characterizes the overall organoleptic, antioxidative and antibacterial properties of fullstrength liquid smokes (Guillen and Manzanos, 1999a; Milly *et al*., 2005; Wei *et al*., 2010). Phenols, carbonyls, and organic acids significantly contribute to smoke condensates' antimicrobial potential (Milly, 2003). Baltes *et al*. (1981) found the major proportion of commercial full-strength liquid smoke to be composed of water (11–92%), acids (2.8–9.5%), tar (1–17%), carbonyl containing compounds (2.6–4.6%) and phenol derivatives (0.2–2.9%).

Naturally occurring phenols in foods are classified as simple phenols, flavonoids, hydroxycinnamic acid and derivatives, and phenolic acids. Phenolic compounds contribute to smoke flavour and colour of liquid smokes, and also have antibacterial and antioxidant properties (Clifford *et al*., 1980; Maga, 1987; Varlet *et al*., 2010). According to Pszczola (1995), phenol is a major antioxidant in liquid smoke. Antioxidative role of liquid smoke is showed by high-boiling phenolic compounds, these compounds are; 2,6-dimetoksifenol; 2,6 dimethoxy-4-metilfenol and 2,6-dimethoxy-4-etilfeno1, they acts as a hydrogen donor to free radicals and inhibit the chain reaction.

Carbonyl-containing compounds impart sweet or burnt-sweet aroma and tend to soften the heavy smoky aroma associated with phenolic compounds with some typical smoke-cured aroma and flavours (Fujimaki *et al*., 1974; Kim *et al*., 1974; Kostyra and Barylko-Pikielna 2006). Research work shows that carbonyls canoccur in amounts rangingapproximately from2.6 to 4.6 percent in commercial liquid smoke condensates (Maga, 1988). Carbonyls inhibit microbial growth by penetrating the cell wall and inactivating enzymes located in the cytoplasm and the cytoplasmic membrane (Milly, 2003). Furthermore, carbonyl-containing compounds are involved in textural changes in smoked food caused by interaction with proteins, and contribute the golden brown colour of smoked products due to reaction with amino acids, and the formation of Maillard reaction by the products (Varlet *et al*., 2007). Freshly prepared liquid smokes are bright yellow; however, colour changes quickly to brown take place because some of the smoke components condense or polymerize rendering the mixture brown (Simko, 2005).

2.15 Liquid Smoke Acidity

Acids influence flavour (tartness), colour, texture and microbial stability of food (Hollenbeck, 1977; Sadler and Murphy, 2003; Rozum, 2007). Acidity of liquid smokes depends on the wood source, processing steps and refining processes (Guillen and Ibargoitia, 1999; Rozum, 2007; Sung *et al*., 2007; Toledo, 2007). Lower pH value represents high quality liquid smoke particularly in its utilization as a preservative (Wijaya *et al.*, 2008; Theron And Lues, 2011) although, Montazeri*et al*., (2013) has reported that the refined liquid smoke has a higher pH and lower titrable acidity. Liquid smokes are usually acidic with a pH of 1.5–5.5 (Toth and Potthast, 1984); however, an alkaline liquid smoke (pH 7.7) prepared from black tea leaves is reported by Sung *et al*., (2007). In the liquid smoke manufacturing process, acids may be neutralized to decrease the harshness of smoke flavour (Toledo, 2007). This change in pH may affect food texture, colour development and flavour intensity (Maga,1987; Fiddler *et al*., 1970).

2.16 Liquid Smoke Yield

Liquid smoke yield is the amount of liquid smoke gotten from the pyrolysis of a known weight of a given wood material. A lot of research has been performed on liquid smoke yield. Study by Guillén and Manzanos, (1999) showed that 100 g of thyme (Thymus vulgariis) powder plants resulted in173 ml of liquid smoke. Thyme is a popular aromatic plant widely used as a spice in food processing, perfumes and popular medicine. It is an endemic plant in some regions of Spain that can grow to a height of 40 cm. While Tranggono *et al*., (1996) found that coconut shell pyrolysis produces 52.85% liquid smoke, 31.75% charcoal and ash and 15.40% of volatile gasses such as: Carbon dioxide, Carbon monoxide, methane and hydrocarbons. Also Swastawati, (2008) obtained 55% liquid smoke and 45% charcoal and evaporate in coconut shell liquid smoke and 46% liquid smoke and 54% charcoal and evaporate in paddy rice chaff.

2.17 Health Risks Associated With Smoked Meat

Smoked foods are generally safe for the consumer provided that they have been produced according to good manufacturing practice from fresh raw material free of natural toxins, chemical contaminants, pathogens, and parasites, and that the storage conditions do not lead to microbial invasion or production of toxins. Among the risks possibly associated with smoked foods is the danger linked to the unlawful use of chemical-preserved wood (Sikorski, 2016). A lot of chemical contaminants such as Polycyclic Aromatic Hydrocarbons (PAHs), dioxins, formaldehyde, nitrogen and sulphur oxides are formed during the combustion of wood in the smoking process (CAC/RCP 68, 2009). Menichini and Bocca, (2003) reported in their study on polycyclic aromatic hydrocarbon that, traditional smoking techniques in which smoke generated from the incomplete combustion of wood comes into direct contact with a food product, can lead to extensive contamination with polycyclic aromatic hydrocarbons (PAHs). PAHs in wood smoke and smoked foods are a major reason for health concern, since many heavy variations of a molecular weight higher than 216 Da have been recognized as mutagenic and/or carcinogenic (Sikorski, 2016). A recent announcement from the World Health Organization (WHO) pointed to the increased risk of cancer, especially colorectal cancer, from the consumption of processed meats(WHO/International Agency for Research on Cancer, 2015).

2.18 Polycyclic Aromatic Hydrocarbons (PAHs)

The term "Polycyclic Aromatic Hydrocarbon, PAH" refers to compounds consisting of only carbon and hydrogen atoms (Arey and Atkinson, 2003). They are a large group of organic compounds containing two or more fused aromatic rings. PAH is formed as a result of incomplete combustion of wood (Simko, 2005). They have been in the recent years, the subject of great concern on human health and environment due to their toxic, mutagenic and/or carcinogenic potentials, the international agency for research on cancer classifies some PAHs as known possibly carcinogenic to human, among these arebenzo[a]pyrene, Naphthalene, chrysene, benzo[k]anthracene, benzo[a]flouranthene and benzo[b]flouranthene (IARC) . PAHs comprised the largest class of chemical compounds known to be carcinogen. Some, while not carcinogenic, may act as precursors (Domingo and Nadal, 2015) PAHs have been detected in both nonprocessed (raw) and processed foods. The presence of PAHs in raw foods is associated with the environmental pollution (Guillen *et al*., 2000). PAHs are found in water, air, soil, and, therefore also in food (Bansal and Kim, 2015). Due to their persistence and high toxicity, a lot of studies have shown that in the aquatic habitat, many organisms, such as fish and shellfish, readily accumulate PAHs from the environment and store them in their tissues reaching levels higher than those in the ambient medium (Dhananjayan and Muralidharan, 2012; Abdel-Shafy and Mansour , 2016). Guillén *et al*., (2000)reported that one of the major factors affecting the level of PAH in smoked food is the method of smoke generation. Also the amount of PAHs depend upon numerous factors, such as the type and composition of wood as well as its moisture content, the temperature of smoke generation, available oxygen and smoking duration (Simko, 2005). The maximum allowable level of PAH is 2 ug/kg wet weight for smoked meats, poultry, and seafood (EC, 2011).

It was reported that while PAH are found in poultry products made by smoking and by addition of smoke flavourings, the products made by traditional smoking had higher PAH concentrations. For instance, turkey breast product made by smoking had 1.9 ug/kg carcinogenic PAH while the same type of product with liquid smoke had no detectable carcinogenic PAH (Gomaa *et al*., 1993). One reason for the reduced levels of PAH in foods with smoke flavourings is the removal of the most toxic compounds by settling. As mentioned, after the smoke is condensed into water, the mixture is stored in tanks to allow a resinous, tar-like substance to settle out. The liquid top layer is decanted and filtered for use (McDonald, 2015).

2.19 Liquid Smoke Applications

Liquid smoke generally offers more flexible applications in various ways. Liquid smoke have been used extensively in food systems to impart flavour characteristics that are similar to smoked food products (Varlet *et al*., 2010). It has been shown that smoke condensate allows the processor to dictate the concentration of smoke being applied more readily than using gaseous smoke (Sunen, *et al*., 2001). Also the mode of application on food product; either spraying,rubbing or dipping (Fellows, 2017).

It has been demonstrated that commercial liquid smoke preparations are effective against various types of spoilage and pathogenic microorganisms (Milly *et al*., 2005). These may be used to preserve quality and ensure safety of foods (Schubring 2008; Martin *et al*., 2010). Maryam (2015) reported the applications of liquid smoke powder as flavour and natural food preservative in sponge cake. Also Snow, (2010) demonstrated that Liquid smoke fractions can be utilized as a reactionary, caramel type flavour in whipped cream. Many different sources of wood vinegar have been recognized as safe, natural inhibitors with various bioactivities, which make them suitable for use in antifungal, termicidal, and repellent applications (Ma *et al*., 2011). Achmadi *et al*., (2013) observed a significant effect of liquid smoke on fly repellency with the highest value of 99.69 using 10% concentration of liquid smoke.

2.20 Sensory Evaluation

Sensory evaluation is defined as a scientific method used to evoke, measure, analyze, and interpret responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone and Sidel, 2004). it uses human panelists and their senses of sight, smell, taste, touch and hearing to measure the sensory characteristics and acceptability of food products, as well as many other materials. Volunteers, consumers or product users are employed to assess the sensory characteristics and provide response (Peter, 2013).Sensory analysis is applicable to a variety of areas such as product development, product improvement, quality control, storage stability, studies and process development (Watts *et al*., 1989).

2.21 Types of sensory evaluation

Sensory evaluation methods comprise a set of measurement techniques with established track records of use in industry and academic research. The principal concern of any sensory evaluation is to ensure that the right test method is chosen to answer the questions being asked about the product, For this reason, tests are usually classified according to their primary purpose (Lawless and Heyman, 2010). There are different types of sensory evaluation test, namely; discriminatory, descriptive and affective test.

2.21.1 Discriminatory test

Also known as simple difference test, have shown to be very useful and are in widespread use today. Typically in a discrimination test, 25-40 participants are used to carry out the analysis. (Lawlessand Heymann, 2010). The tests are mostly used to determine differences among two or more samples. These tests are frequently used when differences among the samples are not obvious but need to be explored. These tests are commonly employed for screening and training of panelists, preliminary assessments, quality assurance and quality control, screening raw materials for consistency and inspecting the effect of ingredient or process changes. Overall, discriminatory tests are swift and can be performed by both simple and skilled evaluators (Sharif *et al*., 2017).

2.21.2 Descriptive test

Descriptive test technique involves judging a product on the basis of its appearance, texture, taste, flavour and mouth feel. It is a very helpful technique as the key words used are made to describe the product for consistency. It is used in the food industry to analyze sensory traits of food products. These are useful in assessing differences among the samples, their perceived sensory attributes and level of variation during processing, packaging and storage on the sensory characteristics of the respective product (Lawless and Heymann, 2010). Sharif *et al*.(2017) reported that, descriptive testing is suitable for understanding the basis of product acceptability, checking the influence of changes in cooking method, recipe or process operations on the sensory attributes, appraising critical parameters that are significant to quality control or shelf-life studies and supervising research and development of food products.Descriptive analysis has proven to be the most comprehensive and informative sensory evaluation tool. It is applicable in the characterization of a wide variety of product changes and research questions in food product development (Lawless and Heymann, 2010).

2.21.3 Affective test

Also known as likeness or preference test is a type of test used to check if there is a clear preference from the majority of respondents (Lawless and Heyman, 2010). These tests are mostly used to establish the consumer acceptability or preference for a particular product through liking and disliking. Affective tests are employed in the food industry to determine preference of one product over another and consumers' intention to use a product. This type of test is used to see if there is a clear preference from the majority of respondents (Lawless and Heyman, 2010). The most commonly used affective methods include paired preferences test, ranking for preference and 9-point hedonic scale (Sharif *et al.*, 2017).

2.22 Properties Assessed in Sensory Analysis of Meat.

Sensory assessment parameters for chicken meat which consist; colour, flavor, profiles, cooking loss/ cooking yield and shear force, have been widely used in scientific studies to validate preprocessing treatments and postharvest processing technologies for chicken meat (Swatland *et al*., 1999; Lyon *et al*., 2001).

i. *Appearance***:** Vision is the first food attribute which is critical in the selection or rejection of food. The appearance of any product is accessed through the vision (Kemp et al. 2009). The appearance of a food can be evaluated in terms of colour, surface characteristics such as smoothness,dryness, glossiness or the exterior appearance such as lump formation, thickness or thinness, layering etc. (Lawless and Heyman, 2017). Color formation in smoked meat products is due to a combination of cold staining and heat-induced Maillard-type chemical reactions (Varlet *et al*., 2007).

ii. *Taste***:** It involves the perception of constituents after being dissolved in saliva, oil or water by taste receptors in the taste buds found superficially on the tongue and other parts of the mouth (Sharif *et al.,* 2017). Senses for taste have a strong influence on the acceptability of food quality. The four primary tastes which are sweet, salt, sour and bitter are not sensed equally. They are affected by time and concentration. The concentration needed to bring about a sensation varies from one individual to another hence, the perception of each taste sensation varies from one individual to another. A food product may be rated as sweet, less sweet, very sweet, depending on the individual's sensitivity to the sweet sensation. However, it is very important to characterize a product on the basis of the attributes it should have and then the product can be rated by various individuals. (Lawless and Heyman, 2010)

iii. *Aroma***:** The aroma or odor associated with food products is sensed by the olfactory receptors present in nasal epithelium. Thus, for the detection of aroma or odor, volatile molecules must be moved to the nasal cavity. These compounds advance in to the nose during inhaling or breathing or during eating through the back of the throat (Sharif *et al*., 2017). A specific odor is the outcome of numerous volatile compounds, but sometimes particular volatiles can be associated with a specific smell, e.g smokiness.

iv. *Flavour***:** this is composed of two subcategories, which are taste and odor. The flavour of a food is judged on the basis of its sensory attributes resulting from the combination of taste and aroma (Sharif *et al*., 2017). Smoky flavour is a complex sensation that is imparted by combinations of different compounds. Thus, a single group of compounds may not necessarily completely bring out the smoke flavour ,Kjallstrand and Petersson 2001. The flavour of smoke components also depends upon its concentration. Therefore, the same smoke flavour may invoke sensory responses of burnt, pungent, and cresolic at high concentration or sweet smoky at a desirable concentration. Also, the acid compounds in liquid smoke such as acetic acid, propionate, butyric and valeric can affect the flavour and texture of smoked meat product (Montazeri *et al*., 2013; Lingbeck *et al*., 2014). These information in the literature submits that not all liquid smoke preparations are the same in terms of flavour and other functional properties, and that each application will benefit from a careful selection of the right smoke flavour (Toledo,2008).

v. *Texture***:** this can be divided into oral texture which involves the mouth feel characteristics, phased changes in the oral cavity and the tactile texture perceived when manipulating the object by hand. There are Various texture attributes used in the process of evaluation, this includes; Adhesiveness, Wetness, Springiness, roughness, cohesiveness, Fracturability, denseness, adhesiveness to teeth, hardness, graininess, softness, chewiness, brittleness. The textural characteristics of a food have a relationship with the appearance of a product. (Sharif *et al*., 2017). Colour formation in smoked products may be due the interaction between carbonyl compounds and amino groups in meat which causes colour changes with the formation of golden brown colour and Maillard reaction in the product during heating process. When using liquid smoke, a cold stain is imparted by the phenolics and acid.Meat colour has a very great influence on food products on consumers acceptance on food especially on meat products and serves as a visual indicator of meat quality (Jones, 1993).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at the Animal Product Laboratory of the Department of Animal Science, Ahmadu Bello University, Samaru, Zaria. Samaru is Located in the Northern Guinea Savanna zone on the longitude 7^0 38' E and 11^0 10' at an altitude 671m above the sea level (Ovimaps, 2019), with an annual rainfall of 1100mm and ambient temperature ranging from 26-32^0C. (IAR/MSU, 2019).

3.2 Experimental Materials

The following materials were used in the course of this research:- a locally fabricated liquid smoke condenser, the three different wood chips gotten from *Parkia biglobosa* (Parkia), *Vitelleria paradoxa* (Shea butter) *and Eucalyptus globulus* (Eucalyptus), a measuring cup, bottles (for storing the liquid smoke), ice blocks (for smoke condensation), dressed broiler chicken meat, salt, vegetable oil, trays, plastic bowls, aluminum foil, kitchen towel, polyethene gloves, food grade paper strainer, laboratory sample containers, charcoal grill, and masking tape (for labeling).

3.3 Wood Chip Preparation and Liquid Smoke Production

The various varieties of the wood chips were locally sourced from fire wood sellers. The wood for the liquid smoke were selected based on their availability in the area. Parkia, Eucalyptus and Shea butter can be found easily in almost all the provinces of Nigeria, especially in the North.

The different wood chips were sorted, labeled and soaked in water at room temperature for 30 minutes prior to pyrolizing. The individual wood chip variety were placed in the pot (fabricated for the purpose of making the liquid smoke as shown in Appendix 5) and placed on the heat, as the wood was burning, the smoke coming out the chimney was trapped and condensed using ice block. Thecondensed smoke was collected and allowed to stand for 48 hours so as to allow the tars and sediments to settle at the bottom of the cup. It was later filtered with a paper strainer and was decantedinto labeled plastic bottles for subsequent use. Small samples of the individual liquid smoke were taken to the Multi-User Research Laboratory at the Chemistry Department, Ahmadu Bello University/ Zaria for laboratory analysis.

3.3.1 Liquid smoke yield

150 grams of the individual wood materials were weighed and pyrolized, the time for complete pyrolysis and the yield of the liquid smoke produced was recorded for each treatment. The charcoal was also measured and the difference between the liquid smoke and the charcoal was recorded as the evaporate.

3.3.2 Physico-chemical analysis of the liquid smoke

Sample of the three individual liquid smoke (20mls) produced was taken to the Multi-User Science Research Laboratory, Department of Chemistry, Ahmadu Bello University, Zaria for their Phyto-chemical properties (quantitative and qualitative). The parameters analysed for the quantitative properties are pH, titrable acidity, carbonyl compounds, phenolic compounds and PAH (Polycyclic Aromatic Hydrocarbon) using HPLC, while the chemical profiles (qualitative) was analyzed using the GCMS (Gas Chromatography and Mass spectrometry) machines. Components of the liquid smoke were quantified as follows; acidity quantified as acetic acid, carbonyls quantified as 2-butanone, and phenols quantified as 2,6-dimethoxy phenol, and PAH as naphthalene. The chemical used wereof analytical grade. Naphthalene, 2- butanone, 2,6-dimethoxy phenol (chemical standards) and chloroform were used for the purpose of chemical analysis of the liquid smokes.

3.3.3 pH and titreatable acidity

A sample of 5 mls was sampled from each liquid smoke and pH was recorded with a Seven-Easy pH meter (Mettler Toledo, Schwerzenbach, Switzer-land). For tittreatable acidity (TA) (as % Acetic acid), the liquid smokes were diluted (1:4 w/v) in distilled water and titrated using 0.1N NaOH as described by Sadler and Murphy (2003). All pH measurements were conducted in duplicate.

3.3.4 Procedure forliquid-liquid extraction for the GCMS analysis

The individual liquid smoke where subjected to liquid-liquid extraction using the procedure as described by Hale (2017) with little modifications. The liquid smoke was extracted using an immiscible solvent, chloroform (GCMS grade). Thirty (30) mls of the individual liquid smoke were measured and was added to twice the volume of chloroform (60mls) in a conical flask. The samples were mixed together for 90minutes in an ultra-sonicator bath which uses vibration and sound waves to mix the samples together. Thereafter, it is allowed to stand for 30min so as to allow it split. The layers formed were separated using a separatory funnel where the chloroform extracted liquid smoke was collected. Two (2) mls of the chloroform extracted liquid smoke was measured and was diluted with chloroform to a ratio of 1:10. 1 µL the mixture was then measured into the GCMS vials for analysis.

3.3.5 GCMS analysis

The liquid smokes were subjected to GC-MS analysis on an Agilent system consisting of a gas chromatoghrapher(model 7890B) and a mass spectrometer detector (model 5977A). The carrier gas was helium (99.99%) with a flow rate of 1 mls/min. The injector and detector temperatures were respectively set at 250^0C and 25^0C. Spectra were obtained over a scan range of 46 to 600 amu at 2 scans/s. The GC program was set as follows: the initial temperature was 60^0C and held for 10 min, then increased by 2^0C/min to 80^0C and held for 5 min, then raised by 2^0C/min to 110^0C and held 6 min, then raised by 2^0C/min to 120^0C and held for 5 min, and finally raised by 5^0C/min to 180^0C and held at 180^0C for 2 min. The chloroform extracted liquid smoke (1.0µL) was injected automatically while maintaining a solvent delay of 4 min. the total run time was 36 minutes. Interpretation of the mass spectrum was made by comparing the peak distribution against the database of National Institute Standard and Technology (NIST/MS 14.0, Gaithersburg, MD, USA). Relative percentages of the chemical compositions were calculated based on the GC peak areas without correction.

3.4 Meat Source and Processing of the Grilled Liquid Smoked Chicken Meat

Dressed whole broiler chicken meats numbering 15 of the same age, average weight, and strain were purchased from the Department of Animal Science, Animal Product Laboratory, Ahmadu Bello University, Zaria. The whole breast of the individualchicken meat were used, they were scored on the surface so as to allow uniform penetration of the experimental ingredients.

The chicken were shared into three bowls where each treatments had 5 numbers of chicken breast per treatments, Ten (10) grams of salt and 20mls of the individual liquid smoke was measured out (Table 3.1). It was then rubbed on the chicken meat and allowed to rest for 30 minute in the refrigerator to allow proper infusion of the ingredients before grilling. The chicken meats were grilled on a charcoal grill to a core temperature of 75^0C.

3.5.1 Proximate analysis

For determining the chemical composition of the chicken meat, 10g of fresh broiler chicken meat sample were analyzed for their proximate composition using the AOAC (2005) procedure. Thereafter, samples from the grilled broiler chicken meat marinated in the different liquid smoke were analyzed at day one for their proximate composition using the AOAC procedure as well.

Table 3.1: Composition of Ingredients For the Broiler Chicken Meat Marinade

Ingredients (g/1kg)	LSMP	LSMS	LSME
Table salt	10	10	10
Liquid smoke	20	20	20
Total	30	30	30

LSMP- liquid smoked meat from parkia, LSMS- liquid smoked meat from sheabutter , LSME- liquid smoked meat from eucalyptus.

The proximate composition analyzed included moisture, dry matter, crude protein, ether extract and ash. This procedure was carried out at the animal science biochemistry laboratory of the department.

3.6 Experiment I: Effect of the Different Liquid Smoke Type Marinade on the Organoleptic Properties of Broiler Meat

3.6.1 Experimental design

The design for this experiment is a completely randomized design (CRD), to evaluate the effect of the three different types of liquid smokes treatments made from*Parkia biglobosa*, *Vitelleria paradoxa and Eucalyptus globulus*having 5 replicates on the organoleptic properties of the grilled liquid smoked broiler chicken meat.

3.6.2 Sensory evaluation

Sensory evaluation of the liquid smoked grilled broiler chicken meat was carried out using the descriptive and affective test method. A total of 20 semi-trained individual panelists were used. Breast meat samples from the differently smoked chicken were cut into small bite sizes approximately to a dimension of 2x2x0.5cm and were served in a coded random order of presentation so as to eliminate bias in the minds of the panelist. The panelist graded the meat samples for its texture, colour, flavour, tenderness, juiciness, smokiness and overall acceptability, they also ranked the samples according to the most preferred irrespective of the earlier scores given. This analysis was carried out and recorded on a sensory evaluation score sheets using the five(5) point Hedonic scale measurement with maximum score of 1 assigned to liked very much while the lowest score of 5 was assigned to disliked very much.

3.7 Experiment II: Effect of Storage Periods of Grilled Broiler Chicken Meat Marinated With Liquid Smoke Obtained From Three Different Woods on Its Sensory Attribute and Shelve Stability

3.7.1 Experimental design

The design for this experiment was a 3X3 factorial arrangement with 5 replicates in a completely randomized design (CRD), which contained the three different types of liquid smokes made from*Parkia biglobosa, Vitelleria paradoxa and Eucalyptus globulus* and three storage periods of 1, 7, 14 days.

3.7.2 Sensory evaluation

Sensory evaluation of the liquid smoked grilled broiler chicken meat was carried out using the descriptive and affective test method. A total of 20 semi-trained individual panelists were used to assess the grilled chicken meat marinated in the different liquid smoke over the three different storage periods (day 1, 3 and 7). Breast meat samples from the differently smoked chicken were cut into small bite sizes to a dimension of approximately 2x2x0.5cm and were served in a coded random order of presentation so as to eliminate bias in the minds of the panelist. The panelist graded the meat samples for texture, colour, flavour, tenderness, juiciness, smokiness and overall acceptability, they also ranked the samples according to the most preferred irrespective of the earlier scores given. This analysis was carried out and recorded on a sensory evaluation score sheets using the five(5) point Hedonic scale measurement with maximum score of 1 assigned to liked very much while the lowest score of 5 was assigned to disliked very much.

3.7.3 Microbiological analysis

The microbial count of the fresh and grilled liquid-smoked chicken meat sample was evaluated at day 1,3 and 7 of storage periods using the pour plate count method to determine their TAPC and

TFC. This was carried out in conformity with the International Commission of Microbiology Specification for Food as outlined by AOAC (2005). The analysis was done in the Microbiology Laboratory of the Department of Microbiology Faculty of Life Science, Ahmadu Bello University, Zaria.

3.7.4 Procedure for total aerobic plate count and fungal count

A sample weighing 10g was dissolved in 90mls of sterile normal saline, the sample was allowed to soak for 10 minutes. A serial dilution was prepared by transferring 1ml of the stock solution into a bottle containing 9mls of sterile normal saline, this gave 10^1 dilution. This was continued until 10^4 dilution was obtained. Then 0.1 ml was transferred from the 10^4 dilution to the surface of Nutrient Agar (for bacteria) and also 0.1ml of 10^2 dilution into a potato dextrose agar (PDA) to inoculateand the inoculum was spread using a spreader (bent glass rod). The Nutrient Agar was incubated at a temperature of 37^0C for 24-48 hours whereas the plates of PDA were incubated at room temperature for 3-5 days.At the end of the incubation periods, the colonies were counted and the results were presented as cfu/g using the formula below:

$$\text{cfu}= \frac{total\ \ no\ of\ colony\ \ counted\ \ \ x\ dilution\ \ factor}{volume\ \ of\ innoculum}$$

3.8 Data analysis

All data collected was subjected to analysis of variance (ANOVA) using the general linear model of SAS software (SAS, 2005). Significant difference among treatments mean were separated using the Duncan Multiple Range Test in the SAS Package.

The models of the experiments are;

Experiment I

$Y_{ijk} = \mu + A_i + E_{ijk}$

Where:

Y_{ij} = is the record of observations for dependent variables;

μ= is the population mean;

A_i = fixed effect ofthe i^{th} treatment (the three different liquid smokes) on the grilled broiler meat

E_{ij} = Random error

Experiment II

$Y_{ijk} = \mu + A_i + B_j + (AxB)_{ij} + Eijk$

Where:

Y_{ij} = is the record of observations for dependent variables;

μ= is the population mean;

A_i = fixed effect ofthe i^{th} treatment (the three different liquid smokes)

B_j = fixed effect of j^{th} storage period (1, 3&7 days).

A X B= the effect of interaction of the i^{th} treatment and j^{th} storage period

E_{ij} = Random error

CHAPTER FOUR

4.0 RESULTS

4.1 Liquid Smoke Yield

The data obtained on the yield of the liquid smoke produced are presented in Figure 1. The values varied numerically. The liquid smoke yield ranged from 18.6-80% with LSE having the highest volume (80%) followed by LSP (33.3%) and the least was recorded for LSS (18.6%). LSS had the highest percentage of evaporate (18.8%) and the least pyrolysis time of 20minutes while LSE had the least evaporate (1.40%) and the highest pyrolysis time of 32minutes.

4.2 Physico-chemical Properties of Liquid Smoke

Table 4.1 shows the physico-chemical properties of the liquid smoke. Five parameters of the liquid smoke were recorded: pH, titratable acidity, carbonyl compound (2- butanone), phenolic compound (2, 6-Dimethoxy phenol) and PAH (Naphthalene). From the result, it was observed that the pH value and titrable acidity varied across the treatment with LSP, LSS and LSE having 4.20 and 0.31, 3.32 and 0.46 then 3.22 and 0.46 respectively. LSP had the highest pH value of 4.20 and lowest tittreatableacidity of 0.31 as compared with the other treatments that had low pH value and higher tittreatable acidity.

The quantity of carbonylic (2-butanone) and phenolic compounds (2, 6 dimethoxy phenol) for LSP, LSS and LSE (Table 4.1) were 3.33 and 0.09; 3.47 and 0; 5.28 and 0.03 mg/ml respectively. LSE had the highest carbonyl containing compounds (5.28mg/ml) while LSP has the highest phenol (0.09mg/ml). The quantity of polycyclic aromatic hydrocarbon (PAH) as represented by the presence of naphthalene (Table 4.1) revealed there were no detectable PAHthroughout the treatments.

4.3 Chemical Compounds in the Individual Liquid Smoke Produced

The GCMS analysis of the liquid smoke identified some chemical compound as shown in Table 4.2. These compounds have similarities ranging from 68-99% with those in the GCMS library. The result showed the total number of the compounds found in the liquid smoke to be 22,18 and 15 for LSP, LSS and LSE respectively.

From the result (Table 4.2) obtained in this study, LSP had the most compounds identified but LSE's compounds had the highest concentrations in terms of the peak areas of the compounds present in it. The major compounds found in LSP were; 2,4-Di-tert-butylphenol (10.51%), cis-13-Octadecenoic acid, methyl ester (5.56), 2,6 dimethoxy phenols also known as syringol (5.81%) and 3,5-dimethoxy-4-hydroxytoluene (2.05%). Followed by LSS whose major components were; 2,4-Di-tert-butylphenol (19.72%), 2,6 dimethoxy phenols (12.56%), 3,5-dimethoxy-4-hydroxytoluene (9.45%) and 5-tert-butylpyrogallol (4.62%) and the least was in LSE with 2,4-Di-tert-butylphenol (18.68%), 2,6 dimethoxy phenols (19.85%), 3,5-dimethoxy-4-hydroxytoluene (10.71 %) , 5-tert-butylpyrogallol (7.22%) and 2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)- (5.03%) as its major compounds.

Most of the compounds identified (Table 4.2) are the same across all the treatments although there were variations in their peak area and retention time. The peak areas indicated that acids, carbonyls, phenols, and organic acids were present in the condensed smoke across all the treatments. The compared properties of liquid smoke produced from Parkia, Sheabutter and Eucalyptus shows that there was no much variations in their chemical composition and quality though, their retention time and peak area were different which means their concentrations are not the same since different plant materials were used in producing the liquid smoke. Most of the compounds across the treatments functions singly or both as an antimicrobial and antioxidant

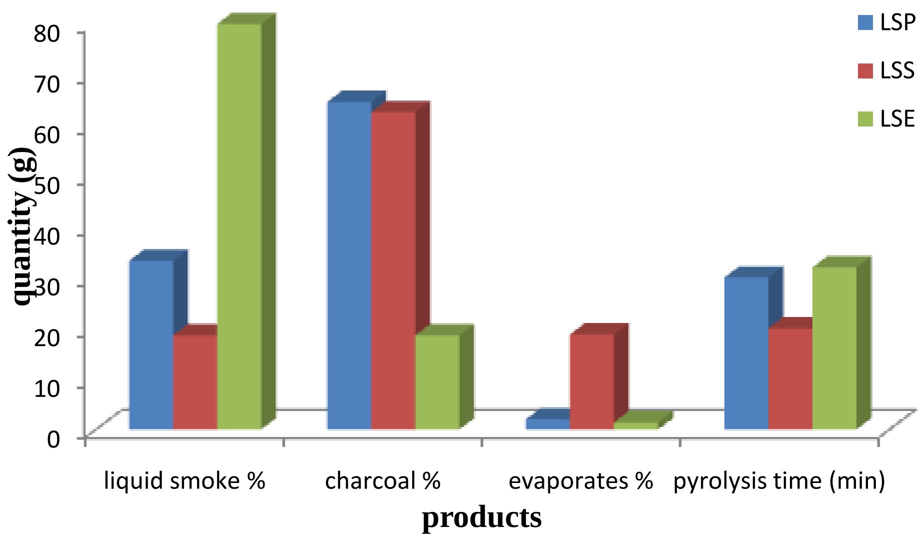

Figure 1: liquid smoke yield from individual wood species.

Table 4.1: Phytochemical composition of the Liquid smoke produced from the three tree wood species

Parameters	LSP	LSS	LSE
pH	4.20	3.32	3.22
Titrable acidity (mg/ml)	0.31	0.46	0.46
Carbonyl compounds(mg/ml)	3.33	3.47	5.28
Phenolic compounds(mg/ml)	0.09	0	0.03
Polycyclic Aromatic Hydrocarbon (mg/ml)	0	0	0

LSP- Liquid Smoke Parkia, LSS-Liquid Smoke Sheabutter, LSE- liquid Smoke Eucalyptus. *(carbonyl containing compounds as 2-butanone, phenols as 2,6, dimethoxy phenol; and PAH as Naphthalene).

Table 4.2: Chemical compounds identified in three different liquid smoke

Names of Compounds	Area (%)		
	LSP	LSS	LSE
Phenol, 4-ethyl-2-methoxy-	-	1.57	-
Phenol, 2,6-dimethoxy-*	4.81	12.56	19.85
Vanillin	-	2.26	
Tridecane*	0.69	2.12	3.15
1-Tetradecene*	0.90	2.21	2.48
Tetradecane*	1.08	2.11	2.28
Naphthalene, 1-methyl-	-	1.68	
Naphthalene, 2-dimethyl-	0.76	-	-
3,5-Dimethoxy-4-hydroxytoluene*	2.05	9.45	10.71
4-hydroxy-2-methoxybenaldehyde	-		1.74
Pentadecane	0.36	0.69	-
2,4-Di-tert-butylphenol*	10.51	19.72	18.68
5-tert-butylpyrogallol	-	4.62	7.22
2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)-*	1.22	2.73	5.03
Ethanone, 1-(4-hydroxy-3,5-dimethoxyphenyl)-	-	-	1.89
Cetene*	1.67	3.06	3.01
3,5-Dimethoxy-4-hydroxyphenylacetic acid	1.07	3.43	-
Hexadecanoic acid, methyl ester	1.03	-	-
Dibutyl phthalate*	2.34	2.79	2.15
n-Hexadecanoic acid	1.03	-	-
cis-13-Octadecenoic acid, methyl ester	5.65	-	-
trans-13-Octadecenoic acid	0.92		
2-Methyl-Z,Z-3,13-octadecadienol	1.39		
beta.-Amyrin	0.31		
3-Eicosine, (E)-	-	3.84	2.97
1-Octadecene*	1.90	4.25	3.99
1-Docosene*	1.64	2.56	2.54
1-Tetracosene	0.80	-	-
Bis(2-ethylhexyl) phthalate	2.75	-	-

LSP- Liquid Smoke Parkia, LSS-Liquid Smoke Sheabutter, LSE- liquid Smoke Eucalyptus

4.4 Effect of Liquid Smoke Type on the Proximate Composition(%) of the Smoked Broiler Chicken Meat

Table 4.3 shows the proximate composition of the differently processed chicken meat and the results indicates that, all parameters analyzed were significantly (P<0.05) affected by the different liquid smoke treatment. The percentage moisture was significantly higher in the fresh broiler chicken meat (56.68) followed by the LSME (44.45), then LSMP (41.15), The least moisture was recorded for LSMS(39.50)

The percentage crude protein (Table 4.3) was significantly higher (P<0.05) in LSMS (38.63) followed by LSME (36.88) and then LSMP (35.00) whose values are statistically the same. The least value was recorded for the fresh chicken meat (20.90). Percentage lipids was also significantly (P<0.05) influenced as shown in Table 4.3 by the various liquid smoke treatments used with the highest value of 20.30 recorded for fresh followed by 15.20 for LSMS and the least in LSMP(14.82) and LSME (14.73) which are statistically the same.The carbohydrate differed significantly with the LSMP (6.36) having the highest value followed by LSME (3.70) then LSMS (3.03) and the least in fresh (1.23). The percentage ash significantlydiffers with the highest value ranging from 3.65 for LSMS to the least value of 0.25 for LSME.

4.5 Effect of the Smoke Type, Storage Period and their Interactions on the Organoleptic Properties of the Smoked Chicken Meat

Tables 4.4 to 4.6 shows the results of the sensory parameters as influenced by the types of liquid smoke, storage periods and their interactions. The result as presented in Table 4.4 revealed that the sensory evaluation for smokiness of the smoked chicken meat has no significant difference (P>0.05) along the treatments. However, other sensory parameters such as colour, flavour, aroma, tenderness, juiciness, overall acceptability and ranking showed significant differences (P<0.05) all through the treatments with the mean values for LSMP having the overall best

Table 4.3: Main effect of liquid smoke source on the proximate composition (%) of the grilled broiler meat

Composition (%)	Fresh	Liquid smoke			SEM	LOS
		LSMP	LSMS	LSME		
Moisture	56.68^{d}	41.15^{b}	39.50^{a}	44.45^{c}	0.56	*
Crude Protein	20.90^{d}	35.00^{c}	38.63^{a}	36.88^{b}	0.45	*
Lipids	20.30^{b}	14.82^{a}	15.20^{ab}	14.73^{a}	0.33	*
Carbohydrate	1.23^{b}	6.36^{a}	3.03^{b}	3.70^{ab}	0.99	*
Ash	0.90^{c}	2.68^{b}	3.65^{a}	0.25^{c}	0.23	*

LSMP- liquid smoked meat from parkia, LSMS-Liquid smoked meat sheabutter, LSME- Liquid Smoked meat eucalyptus, ^{abc} – means within the treatments having different superscript differs significantly. SEM- standard error mean, LOS- levels of significance.

Table 4.4: Main effect of the smoke source on the organoleptic properties of the grilled broiler meat

Parameters	Liquid Smoke types			SEM	LOS
	LSMP	LSMS	LSME		
Colour	1.83^{a}	1.77^{a}	2.08^{b}	0.10	*
Flavour	1.80^{a}	2.03^{b}	2.14^{b}	0.11	*
Aroma	2.06^{b}	2.06^{a}	2.21^{b}	0.29	*
Tenderness	1.89^{a}	2.31^{b}	2.12^{b}	0.13	*
Juiciness	1.95^{a}	2.27^{b}	2.29^{b}	0.13	*
Smokiness	2.08	2.17	2.27	0.14	NS
Overall acceptability	1.88^{a}	1.96^{ab}	2.14^{b}	0.11	*
Ranking	1.71^{a}	2.06^{b}	2.20^{b}	0.10	*

LSMP- liquid smoked meat from Parkia, LSMS-Liquid smoked meat sheabutter, LSME- Liquid Smoked meat eucalyptus, ^{abc} – means within the treatments having different superscript differs significantly, SEM- standard error mean, LOS- levels of significance, NS-not significant.

score followed by LSMS and the least score in LSME. The physical colour or appearance of the liquid smoked chicken meat was of the same usual standard (golden brown).

The effect of the storage period on the organoleptic properties of the meat as shown on Table 4.5 Showed that there was significant difference ($P<0.05$) in the liquid smoked meat with respect to its sensory qualities and overall acceptability throughout the three different storage periods. There was reduction in the sensory scores as the storage period increased. Day 1 had the best sensory score followed by day 3 and the least score was recorded for day 7.

Interaction of the smoke type and the storage effect of the liquid smoked meat and storage periods, on the organoleptic properties smoked chicken (Table 4.6) showed that there was significant difference on the interaction, because it was discovered that the sensory scores decreased as the storage periods increased. There was no interaction between the storage periods and the treatment in the score forcolour in LSMP, flavour in LSMS. Also the score for colour, flavour, aroma, overall acceptability and ranking in LSME was the same throughout the storage periods.

4.6 Effect of Treatment, Storage Period and Their Interaction on the Microbial Properties of Liquid Smoked Broiler Chicken

Tables4.7 to 4.9 shows the results of the microbial counts of the fresh broiler chicken and grilled broiler chicken meat as influenced by the treatments, storage periods and their interactions. All the mean values for the microbial properties of the meat products fell within the acceptable range of (10^6-$<10^7$) as specified by the International Commission for Microbiological Specifications on Food(2014).

The initial microbial value for TAPC and TFC for the fresh broiler meat wasn't above 10^6 (Table 4.7). The result showed that the microbial counts of the liquid smoked broiler chicken meat varied across the treatments and throughout the different storage periods. There was no

Table 4.5: Main effect of storage periods on the organoleptic properties of the grilled broiler chicken meat

Parameters	Storage period (day)			SEM	LOS
	1	3	7		
Colour	1.73^{a}	1.92^{b}	2.02^{c}	0.10	*
Flavour	1.60^{a}	2.03^{b}	2.32^{c}	0.11	*
Aroma	1.89^{a}	2.72^{b}	2.35^{a}	0.29	*
Tenderness	1.65^{a}	1.89^{a}	2.81^{b}	0.12	*
Juiciness	1.65^{a}	2.20^{b}	2.63^{c}	0.12	*
Smokiness	1.65^{a}	2.44^{b}	2.35^{b}	0.13	*
Overall acceptability	1.75^{a}	2.03^{b}	2.19^{b}	0.11	*
Ranking	2.00^{b}	1.97^{a}	2.00^{b}	0.10	*

^{abc} – means within the treatments having different superscript differs significantly, SEM- standard error mean , LOS- levels of significance.

Table 4.6: Interaction effect of the smoke source and storage periods on the organoleptic properties of grilled broiler chicken meat

Parameter	Liquid smoke type and storage periods (day)									SEM	LOS
	LSMP			LSMS			LSME				
	1	3	7	1	3	7	1	3	7		
Colour	1.80^{b}	1.92^{b}	1.76^{b}	1.45^{a}	1.79^{b}	2.10^{b}	1.95^{b}	2.08^{b}	2.19^{b}	0.10	*
Flavour	1.90^{a}	3.56^{b}	2.43^{a}	1.65^{a}	2.12^{a}	2.38^{a}	1.85^{a}	2.48^{a}	2.24^{a}	0.29	*
Aroma	1.40^{a}	1.92^{b}	2.04^{b}	1.40^{a}	1.96^{b}	2.71^{c}	2.00^{b}	2.20^{b}	2.19^{b}	0.10	*
Tenderness	1.40^{a}	1.76^{b}	2.52^{d}	1.70^{b}	2.12^{c}	3.14^{f}	1.85^{b}	1.80^{b}	2.75^{c}	0.11	*
Juiciness	1.60^{a}	2.12^{b}	2.09^{b}	1.65^{a}	2.20^{b}	2.95^{c}	1.70^{a}	2.80^{c}	2.85^{c}	0.12	*
Smokiness	1.45^{a}	2.40^{b}	2.29^{b}	1.70^{a}	2.44^{b}	2.29^{b}	1.80^{a}	2.48^{b}	2.48^{b}	0.14	*
Overall acceptability	1.65^{a}	2.00^{b}	1.95^{b}	1.60^{a}	1.88^{b}	2.43^{c}	2.00^{b}	2.20^{b}	2.19^{b}	0.11	*
Ranking	2.00^{c}	1.72^{b}	1.43^{a}	1.75^{b}	2.12^{c}	2.28^{c}	2.25^{c}	2.08^{c}	2.29^{c}	0.10	*

LSMP- liquid smoked meat from parkia, LSMS-Liquid smoked meat sheabutter, LSME- Liquid Smoked meat eucalyptus, ^{abc} – means within the treatments having different superscript differs significantly SEM- standard error mean, LOS- levels of significance.

4. 7: Microbial count of fresh broiler chicken meat (cfu/g)

Parameters	Fresh
TAPC	$7.0x10^6$
TFC	$1.3x10^3$

TAPC- Total aerobic plate count, TFC- Total fungal count, cfu- coliform forming unit significant difference (P>0.05) as shown in Table 4.8 for TAPC across the treatments. However, significant difference was observed for TFC with the highest counts recorded for LSMS ($1.6x10^2$) while the least was recorded for LSMP ($6.3x10^1$) and LSME ($3.3x10^1$) whose values were statistically the same. The microbiological analyses when compared with the fresh broiler chicken meat (Table 4.7) showed that the microbial counts on all the samples decreased with the application of smoking process.

Significant difference (P<0.05) was observed all through the storage periods as presented in Table 4.9. In all the storage days, day 3 had the highest microbial countacross all the parameters monitored. Day 3 had the highest count ($7.1x10^4$) for TAPC followed by day 1 ($8.25x10^2$) and day 7 ($2.17x10^3$) whose values are statistically the same. The highest TFC was recorded also for day 3 ($1.76x10^2$) followed by day 1 ($8.0x10^1$). There was no fungal count recorded at day 7.

Table 4.8: Main effect of the smoke source on the microbial properties of the grilled broiler chicken meat (cfu/g)

Parameters	Liquid smoke type			SEM	LOS
	LSMP	LSMS	LSME		
TAPC	$2.2x10^{4}$	$3.8x10^{4}$	$1.4\ x10^{4}$	27444.2	NS
TFC	$6.3x10^{1a}$	$1.6x10^{2ab}$	$3.3x10^{1a}$	67.88	*

LSMP- liquid smoked meat from parkia, LSMS-Liquid smoked meat sheabutter, LSME- Liquid Smoked meat eucalyptus, TAPC- Total aerobic plate count, TFC- Total Fungal Count, cfu- coliform forming unit,^{abc} – means within the treatments having different superscript differs significantly (P<0.05), SEM- standard error mean, LOS- levels of significance, NS- not significant, *-significant.

Table 4.9: Main effect of storage periods on the microbial characterization of grilled broiler chicken meat(cfu/g)

Parameters	Storage periods			SEM	LOS
	1	3	7		
TAPC	$8.25x10^{2a}$	$7.1x10^{4b}$	$2.2x10^{3a}$	13035.3	*
TFC	$8.0x10^{1ab}$	$1.8x10^{2b}$	0^{a}	56.57	*

TAPC- Total aerobic plate count, TFC- Total Fungal Count, CFU- coliform forming unit, ^{abc} – means within the treatments having different superscript differs significantly (P<0.05),SEM- standard error mean, LOS- levels of significance, *-significant**.**

CHAPTER FIVE

5.0 DISCUSSION

5.1 Liquid Smoke Yield

The liquid smoke yield ranged from 18.6-80%. It was observed that liquid smoke eucalyptus (LSE) had the highest yield of liquid smoke (80%), the longest time of pyrolysis (32 mins) with 1.4% evaporates followed by liquid smoke parkia (LSP) and the least liquid smoke yield was obtained in liquid smoke sheabutter (LSS) which had the least pryrolysis time of 20 min and the most evaporate (18%). These result obtained is not in consonant with what was reported by Swastawati (2008) who obtained 55% liquid smoke and 45% charcoal and evaporate in coconut shell liquid smoke and 46% liquid smoke and 54% charcoal and evaporate in paddy rice chaff. The differences observed in yield may be due to the variation in the biological characteristics of the different wood materials that were used in making the liquid smoke and also may be due procedure for obtaining liquid smoke.

5.2 Physico-Chemical Properties of Liquid Smoke

The compared properties of wood smoke produced from Parkia, Sheabutter and Eucalyptus wood showed that the physico-chemical properties of the liquid smoke produced varied across the treatments.It was observed that the liquid smoke were dark brown in colour for LSP and yellow in colour for LSS and LSE and their odor was observed to be very smoky. All the liquid smoke produced in this study were acidic ranging from a pH of 3.22-4.2, this is in agreement with Indiarto *et al*., (2019) who reported that liquid smoke has acidic properties, thus the higher the concentration of liquid smoke added, the lower the pH value of the smoked product which in turn means better keeping of the meat products. The amount of acidity of liquid smokes depends on the wood source, processing steps and refining parameters (Rozum, 2007; Sung *et al*., 2007;

Toledo 2008). pH of the liquid smoke influences the microbial stability of food, tartness (flavour), colour and texture (Sadler and Murphy 2003; Rozum 2007). The pH values (ranging from 3.22-4.2) observed in this study where within the range reported by Toth and Potthast (1984) who reported a pH range of their liquid smoke to be 1.5-5.5.

Berhimpon *et al.* (2018) reported that an increase in the phenolic content of the liquid smoke causes decrease in its pH, but this wasn't the case in this study. This may be due to the differences in the type, age, composition (cellulose, hemi cellulose and lignin) of the wood materials used, and the smoke generation method employed. LSP had the highest pH value of 4.2 and lowesttitratable acidity of 0.31 as compared with the other treatments that had low pH value and higher titratable acidity. these trend observed is in line with what was reported by Wijaya *et al.* (2008) who mentioned that the higher the organic acids the lower the acidity and vice versa. The pH value obtained for LSP is the same with the values observed by Sung *et al.* (2007) in his evaluation of bread flour liquid smoke. Liquid smoke made from Eucalyptus appears to be the best in terms of it pH value (3.22) since it has been reported that low pH value represents high quality of liquid smoke particularly in its utilization as food preservatives (Wijaya *et al*., 2008; Theron and Lues, 2011).

The result for the carbonylic compounds ranged from 3.33-5.28 with LSE having the highest carbonyl containing compounds. These values shows little discrepancies with the range reported by Maga (1988) who observed that carbonyls can materialize in amounts ranging approximately from 2.6-4.6 percent in commercial liquid smoke condensate. The carbonyl compound in liquid smoke contributes to the golden brown colour of the product. Interaction between carbonyl compounds and amino groups in meat causes colour changes with the formation of golden brown colour and Maillard reaction in the product (Varlet *et al*., 2007).

Carbonyls in liquid smoke also functions as antimicrobial, they inhibit microbial growth by penetrating the cell wall and inactivating enzymes located in the cytoplasm and the cytoplasmic membrane (Milly, 2003). The phenolic compounds of the liquid smoke produced in this study as indicated by the concentration of 2,6-dimethyoxyphenol had a value ranging from 0 to 0.09 mg/ml this is not in agreement with the result obtained by Maga (1988) and Achmadi (2013). However, the values observed though very low fell within the range reported by Milly *et al*. (2005), who reported 0-5mg/ml for the phenolic contents in their F4 liquid smoke evaluations. The difference observed in the result obtained from this research may be attributed to variation in the type of wood and their species.

Liquid smoke has been considered to be a source of natural phenolic compounds, which contributes to the colour of the meat product as well. However, these compounds mainly contribute to the smoky taste and aroma, they also have antibacterial and antioxidant properties (Varlet *et al*., 2010; Indiarto *et al*., 2019). The overall result for the physico-chemical composition (pH, carbonyls, and phenolics) of the various liquid smoke showed that therewere some similarities observed with the result reported by Milly *et al*. (2005).

In addition to phenolic compounds, carbonyl, and acids, wood pyrolysis also produces dangerous compounds of polycyclic aromatic hydrocarbon (PAH) groups such as benzo(a)pyrene, naphthalene, flouranthene e.t.c. PAH compounds are formed at a temperature from 500-900^oC. The PAH content as represented by Naphthalene showed that there was no traceable amount of PAH in all the liquid smokes produced, this indicates that the sedimentation and the filtration process of the liquid smoke as reported by Darmadji, (2002) and Simon *et al*. (2005) had effect in the removal of the PAH, hence is considered safe for consumption since it is below the maximum allowable level of 0.02ppm (EC, 2011).

5.3 Chemical Compounds Identified in the Individual Liquid Smokes Produced

The chemical compound of liquid smoke varied based on their specific characteristics, although the major component are usually groups of phenols, acids, aldehydes, ketones, furans, etc. (Swastawati, 2008). More than 200 chemical constituents of liquid smoke have been identified from different wood resources (Yang *et al*., 2016).

The chemical compounds in the liquid smokes produced in this study asrevealed by the GCMS machine have similarities ranging from 68-99% with those in the GCMS library. The peak areas indicated that acids, carbonyls, phenols, and organic acids were present in the liquid smoke produced.Most of the compounds identified across the treatments functions singly or both as an antimicrobial and antioxidant

Some of the chemical compounds even though similar to the findings of Montazeri (2013), Toledo (2008) and Milly *et al*. (2005), still varied widely in terms of their retention time and peak areas. The differences observed in the presence and absence of some compounds across the treatments may be attributed to the variations in the type of wood used, the moisture content, and the rate of aeration during smoke generation. This is in agreement with Toledo (2008) who reported that not all published data on smoke composition reported by different authors have the same compounds. Therefore, the concentration of the different compounds and types varied among the treatments.

5.4 Effect of Liquid Smoke Source on the Proximate Composition of the Grilled Broiler Chicken Meat

The statistical analysis of the proximate composition of the processed broiler chicken meat revealed that, all the physicochemical parameters monitored (moisture, protein, lipids, carbohydrate and ash) were significantly ($P<0.05$) affected by the different liquid smoke treatment used. This indicates that the chemical compounds of the individual liquid smoke affected the proximate composition of the broiler chicken meat. This is not consistent with what was reported by Sisko *et al*. (2007) and Yusnaini *et al*. (2012) who stated that the physicochemical composition of trout fish and beef were relatively the same after the application of liquid smoke but agreed with the findings of Swastawati*et al*. (2014), who stated that there was significant difference in the proximate composition of smoked milk fish using corncob liquid smoke.

The percentage moisture was significantly higher in the fresh broiler chicken meat as compared with the rest of the liquid smoked broiler meat treatments. This corresponds with Zuraida *et al*. (2011) who reported that liquid smoke can induce dehydration on food product. The least moisture was recorded for LSMS which in the long run enhances the better keeping quality of the meat product since moisture content is one of the major factors that aid spoilage in meat and meat products (Oparaku and Mgbenka, 2012).

The percentage crude protein was significantly higher in LSMS (38.63), followed by LSME (36.88), then LSMP (35.00). The least value was recorded for the fresh chicken meat,these result indicates that protein content increased with the reduction of moisture content and is in agreement with what was reported by Aliya *et al*. (2012) in a study on the “Effect of the freshness of starting material on the final product quality of dried salted shark”.

5.5 Effect of the Smoke Source, Storage Period and Their Interactions on the Organoleptic Properties of the Grilled Broiler Chicken Meat

The organoleptic properties such as; colour, flavour, texture, tenderness juiciness and acceptability are important components of consumer’s preference on meat consumption which may vary from products to products depending on the breed, processing methods and locality of the products. Thescore for thesensory evaluation for smokiness of the grilled chicken meat marinated in the different liquid smoke showed no significant difference ($P>0.05$) across the treatments. However, other sensory parameters such as colour, flavour, aroma, tenderness, juiciness, overall acceptability and ranking showed significant differences ($P<0.05$) all through the treatments with the mean values for LSMP having the overall best score followed by LSMS and the least score in LSME.

Meat colour is an important attribute in meat consumption as it positively relates to the consumers acceptability of the meat product. LSMS was the most preferred in terms of their colour with a score of 1.77, this may be due the interaction between carbonyl compounds and amino groups in meat which causes colour change. Also the application methods (rubbing) of the liquid smoke may have contributed to the colour as when using liquid smoke, a cold stain is imparted by the phenols but when the product is heated, the carbonyl compounds reacts with the protein in the meat (Varlet *et al*., 2007). There was a typical smoked chicken aroma observed on all the meat products analyzed.

Liquid Smoked Meat Parkia (LSMP) had the best score (1.80) for flavour. This could be attributed to the phenolic compounds innate in the Liquid Smoke Parkia (LSP) used in processing it. Interestingly, it had the highest phenolic compound of 0.09 mg/ml. This is in concurrence with what was reported by Toledo (2008) who stated that smoky aroma and flavour in meat products is also influenced by the phenolic content of the liquid smoke. The higher the concentration of the phenolic contents in liquid smoke the more the smokiness of the meat product (Indiarto *et. al.,* 2019). All the meat samples across the treatment showed satisfactory values for smokiness, this probably is because the panelist could recognize the smoky flavour on the meat treated with the varieties of liquid smoke. There was however a significant difference ($P<0.05$) observed in the smokiness of the broiler chicken meat over the 3 different storage periods , the highest score for smokiness was recorded in day 1 and reduced subsequently which may be due to the diffusion of the smoky aroma into the air since the smoked meat was stored openly at ambient temperature.

Throughout the storage periods, day 1 had the best overall acceptability, followed by day 3 and day 7 which werethe least acceptable. The high score observed in day 1 may be because the liquid smoked chicken meat is still fresh and juicy while the subsequent reduction in moisture content and fat rancidity may be a major contributory factor for the low score at day 3 and 7. All the organoleptic properties scoresof the meat monitored decreased as the storage days increased with its highest values at day 1 followed by day 3. Day 7 had the least score. This is in agreement with Stetzer *et al*. (2008) who stated that positive flavour compounds reduces with aging and negative compounds increases. Though all the values were still above average on the 5 point hedonic scale.

The interaction effect between the treatment and storage periods where significantly different ($P<0.05$) for all the parameters monitored.But there were no significant differences observed on the score for flavour, aroma, overall acceptability and the ranking for LSME. This shows that LSE showed themost antioxidant effect among all the liquid smoke tested. There was also difference in colour for LSMP and LSME throughout the storage periods. The score for tenderness highly varied with the highest score recorded for LSMP at day 1 and the least score recorded for LSMS at day 7.

On the overall assessment of the results, the mean scores of the parameters across all the treatments showed that LSMP was the most preferred by the panelist, followed by LSMS. The least preferred was LSME, though it seems to have performed the best in terms of its microbial properties and consequently the keeping quality of the broiler chicken meat.

5.6 Effect of Treatment, Storage Period and Their Interaction on the Microbial Properties of Grilled Broiler Chicken

The antimicrobial properties of smoke are well known and constitute the primary role of smoke in food preservation. The antimicrobial action of liquid smoke observed in this study could be attributed to the presence of phenolic, carbonylic and organic acids components in the liquid smoke which are known to alter the permeability of the microorganism's membrane, causing damages to the point of intracellular leakages. These constituents (Phenolics, organic acid, and carbonyls) individually have antimicrobial activity but their combined effect, is interacting (Toledo, 2008). The count for the TAPC and TFC were 7.0×10^6 and 3.0×10^3 respectively, fell within the acceptable range (10^6-$<10^7$) as prescribed by International Commission for Microbial Specifications on Foods (2014) and is thereby fit and safe for human consumption so long as further processing is employed.

The mean counts for the effect of liquid smoke type on the microbial characterization of the broiler meat marinated with the different liquid smoke ranges from 1.4×10^4-3.8×10^4 and 3.3×10^1-1.6×10^2 for TAPC and TFC respectively. There was no significant difference on the microbial counts for TAPC. However, significant difference was observed for their TFC across the treatment. LSME had the best results in terms of the microbial counts of the grilled broiler chicken meat since it had the least microbial count. This may be because it has the highest acidity, titterable acidity and carbonylic compounds (3.22, 0.46 and 5.28 mg/ml respectively). This in turn means that LSE showed the most versatile antimicrobial potential on preservation out of all the liquid smokes tested which agrees with what was reported by Milly (2003) who reported that the most effective liquid smoke fraction with the highest antimicrobial activity is one with low pH and high carbonyl compound. The general variations observed in the counts across the treatment could be attributed to the differences in the wood material used and differences in the composition of their liquid smoke, this is in concurrence with Toledo (2008) who stated that the microbial Inhibitory activity of a liquid smoke varies with different preparations.

Significant (P<0.05) difference was observed on the effect of the storage periods on the microbial characterization of the grilled broiler chicken meat. The result for the microbial counts did not follow what was reported by Indiarto *et al*. (2019) who stated that liquid smoke type and the length of storage has positive effect on the microbial count of the product in their findings on the antimicrobial properties of liquid smoke on beef meat ball. Day 3 had the highest microbial count compared to day 1 and day 7, day 7 had the least microbial count. The general trend of the microbial count observed in this study is that it rose at day 3 and dropped over time at day 7 storage. This trend observed is similar to what was reported by Ebabhamiegbebho*et al.*(2011). The reason for the reduction in the microbial count of the liquid smoked chicken at day 7 may have been due to the further reduction in moisture content of the meat product since liquid smoke is known to induce dehydration (Zuraida*et. al*., 2011) which in the long run enhances the shelf life of the product as it become unfavorable for attack, growth and multiplication of spoilage organisms.It has been reported also that, dried foods are capable of increasing in their shelf life if the environment is dry and remained constant and this result in the loss of moisture into the atmosphere.The constant immediate environment of such packaged and stored food prevents hysteresis, thereby prolonging the shelf-life of such product (Ebabhamiegbebho*et al.*, 2011).

All the mean values for the microbial counts (TAPC and TFC) of the grilled broiler chicken meat marinated with different liquid smoke though, significantly (P<0.05) different, fell within the acceptable range (10^6 -<10^7) of the International Commission of Microbiological Specifications for Foods (2014) and also below the Nigerian Agency for Food and Drug

Administration and Control (NAFDAC, 2009) specification which is $5.0x10^5$-$1.0x10^6$ respectively. Therefore, from the microbiological point of view the use of eitherLSE, LSP or LSS liquid smoke is promising as an alternative preservation method to traditional smoking. Although, LSE performed best in preserving thegrilled broiler chicken meat across the storage periods (7 days).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

An experiment was conducted on the comparative evaluation of liquid smoke made from three different wood verieties *(Parkia biglobosa, Vitelleria paradoxa and Eucalyptus globulus)* for their quality attributes on broiler meat. There was variation in the liquid smoke yield obtained from the various wood species used, in which LSE had the highest liquid smoke yield of (80%) and the least evaporate (1.40%) followed by LSP and LSS.

On the physico-chemical properties of the liquid smoke, Five parameters of the liquid smoke were observed: pH, titterable acidity, carbonyl compound (2- butanone), phenolic compound (2,6-Dimethoxy phenol) and PAH (Naphthalene). It was noticed LSE had the most concentration of the components having the pH of 3.22, titterable acidity of 0.46, carbonyls 5.28except for the phenolic components which was the highest in LSP (0.09).

The chemical compound as identified by the GCMS has similarities ranging from 68-99% with those in the GCMS library. The result showed the total number of the compounds found in the liquid smoke to be 22 for LSP, 18 for LSS and 15 for LSE respectively.

The proximate composition of the grilled broiler chicken meat marinated in the tree different liquid smoke showed there was significant ($P<0.05$) effect of the liquid smoke applications on all treatments with the highest moisture content found in LSME (44.45%). Protein (38.63%), lipids (15.20%) and ash (3.65%) was higher in LSME and carbohydrate (6.36%) was higher in LSMP.

Significant difference was observed during the storage periods with day 1 having the best score. Sensory properties of the various liquid smoked broiler chicken meat varied significantly

(P>0.05) among the treatments. The overall acceptability (1.88) and ranking (1.71) indicates that LSMPwas more acceptable as compared to the other treatments.

There was no significant (P>0.05) effect of the liquid smoke on the TAPC of the liquid smoked broiler chicken meat across the treatment. However significant difference (P<0.05) was noticed on their TFC with LSME being the best having the least score of $3.3x10^1$. All the microbial count obtained from this study was within the range ($10^6$to $<10^7$) as specified by standard microbial load specification on animal food products and also below the Nigerian Agency for Food and Drug Administration and Control (NAFDAC) specification which is $5.0x10^5$ and $1.0x10^6$. The meat products produced is therefore fit for consumption.

6.2 Conclusions

From the findings of this study, the following conclusions were made:

i. There were variations in the physico-chemical properties of the liquid smoke produced with Liquid smoke eucalyptus (LSE) having the most liquid smoke yield and the best phyto-chemical properties which means it had the best preservative effect on the broiler chicken meat.

ii. The proximate composition in all the treatments were not thesame although, LSMS had the best proximate composition followed by LSMP and the least was in liquid smoked meat eucalyptus (LSME)

iii. LSMP had the best organoleptic properties as it had the best overall acceptability and ranking among all the meat samples tested

iv. All the liquid smoke treatment positively affected the storage periods but LSME had the strongest antimicrobial and antioxidant action on the samples thereby giving the best shelf life (7 days) of the products stored at ambient temperature.

6.3 Recommendations

The following recommendations were made based on the findings obtained in this study:

i. LSMP has the highest overall acceptability and ranking and is recommended for use as a smoke flavour on broiler chicken meat.

ii. Interms of the antimicrobial action of the liquid smoke use on the broiler chicken meat, LSE is recommended for longer storage (7 days) in an ambient temperature.

iii. Further research should be carried out on the effect of dilution strength of liquid smokefrom LSP, LSS and LSE on the sensory, antimicrobial and proximate properties of the broiler chicken meat.

iv. Research into the antimicrobial and sensory properties of liquid smoke produced from other wood materials (e.g sugarcane chaff) is recommended, so as to ease the pressure on deforestation and environmental pollution.

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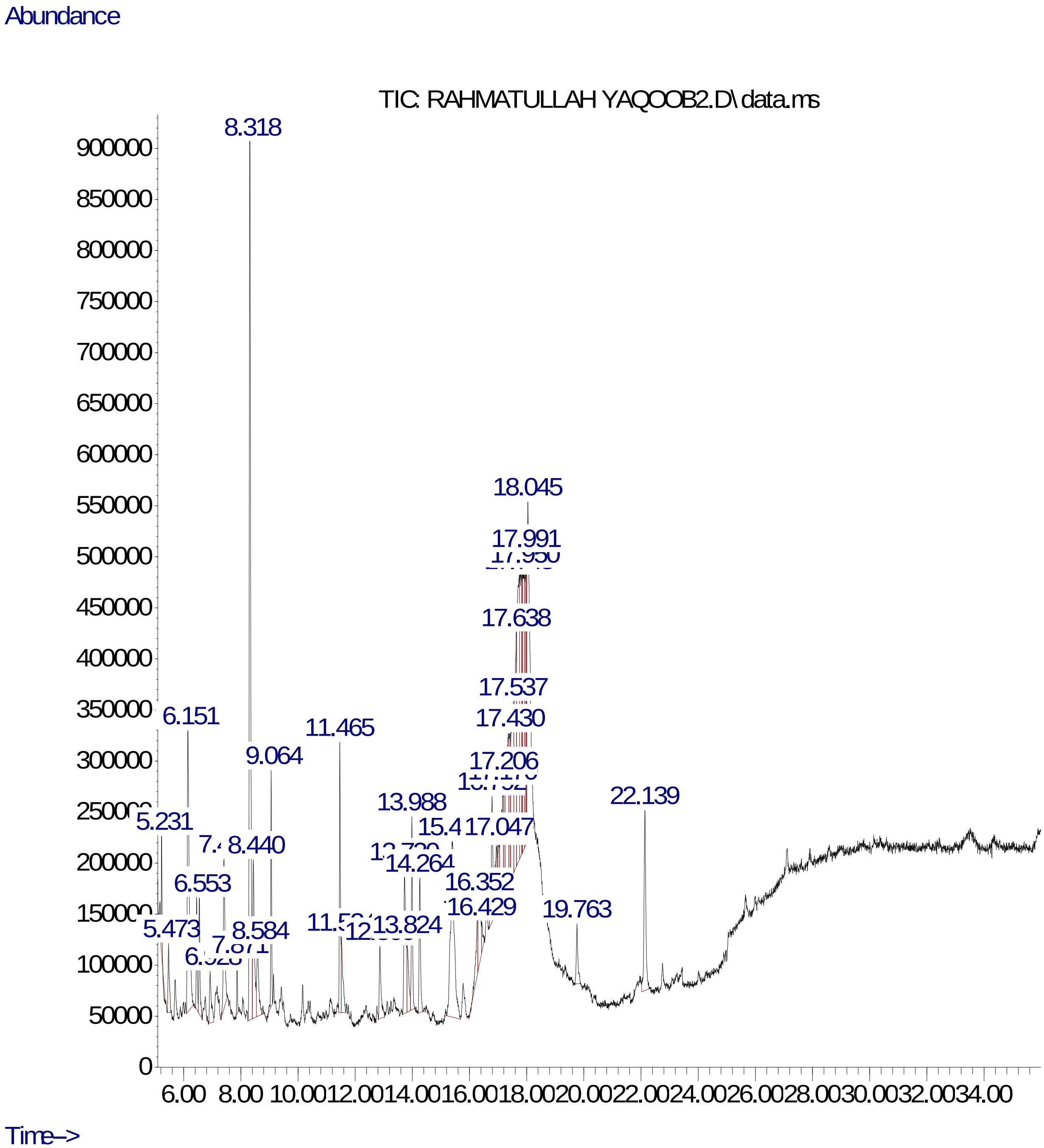
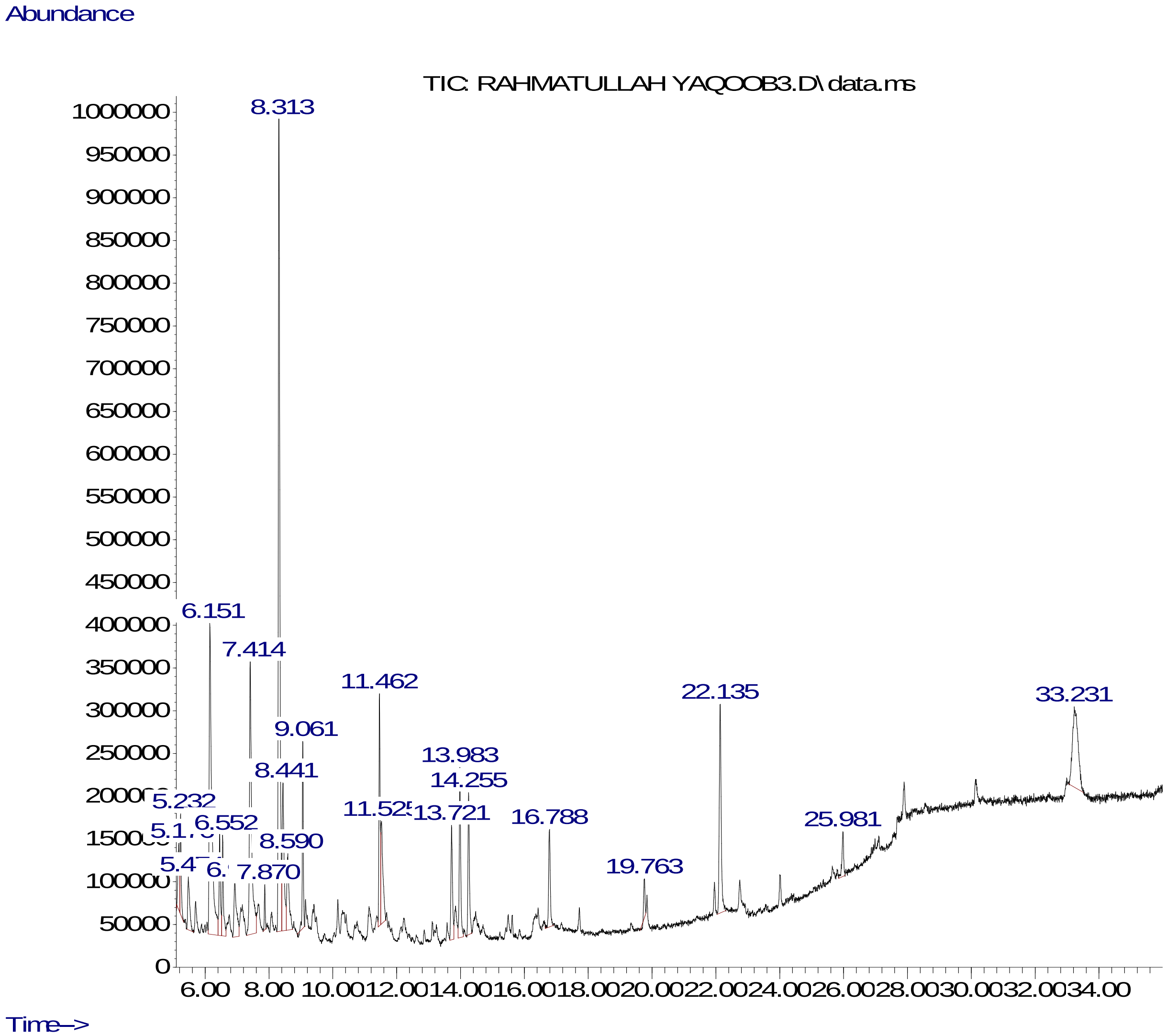
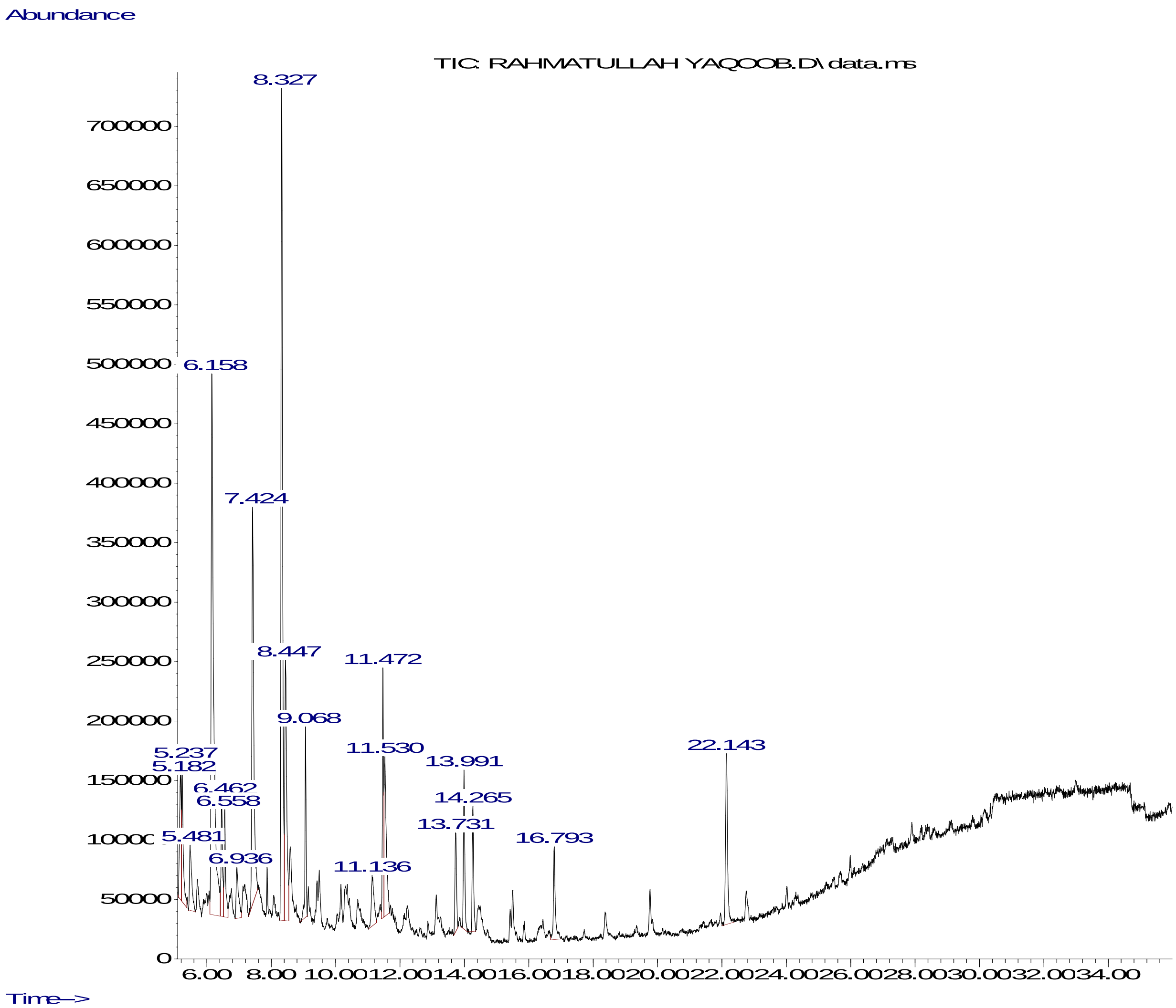
APPENDIX 1: GCMS GRAPHS FROM THE LIQUID SMOKES PAKIA (LSP)



APPENDIX2: GCMS GRAPHS FROM THE LIQUID SMOKES SHEABUTTER (LSS)



APPENDIX 3: GCMS GRAPHS FROM THE LIQUID SMOKES EUCALYPTUS (LSE)



APPENDIX4: PICTURES OF DIFFERENT WOOD TREE SPECIES AND THEIR WOOD CHIPS

Parkiabiglabosa tree

Parkia biglabosa wood chips

Vitteleria paradoxa tree

Vitteleria paradoxa wood chips

Eucalyptus globulus tree

Euc*alyptus globulus* wood chips

APPENDIX 5: LIQUID SMOKE PRODUCTION SET UP

Liquid smoke production set-up

APPENDIX 6: RAW LIQUID SMOKE AND LIQUID SMOKE CHLOROFORM EXTRACT

Raw liquid smoke from the different wood

Liquid smoke chloroform extract

APPENDIX 7: SENSORY SCORE SHEET

DEPARTMENT OF ANIMAL SCIENCE

FACULTY OF AGRICULTURE

AHMADU BELLO UNIVERSITY, ZARIA-KADUNA STATE.

A Sensory Score Sheet

1. **You have been provided with three meat samples; please score them according to the five point hedonic scale.**

Sample	Colour	Aroma	flavour	Tenderness	Juiciness	Smokiness	Overall acceptability
417							
276							
391							

KEY

1-Like very much
2- Like moderately.
3- Neither like nor dislike
4- dislike moderately
5- dislike very much.

2. **Please rank the samples according to your preference.**

Ist: [ ]   2nd: [ ]   3rd: [ ]