EFFECTS OF SMOKING, FRYING AND FREEZING ON NUTRIENT COMPOSITION, MICROBIAL QUALITY AND SHELF LIFE OF *CLARIAS GARIEPINUS*BURCHELL, 1822

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MAY, 2017

DECLARATION

I declare that the work in this dissertation entitled **"EFFECTS OF SMOKING, FRYING AND FREEZING ONNUTRIENT COMPOSITION, MICROBIAL QUALITY AND SHELF LIFE OF *CLARIAS GARIEPINUS* BURCHELL, 1822"** has been carried out by me in the Department of Biology, Ahmadu Bello University, Zaria; Nigeria. The information derived from the literature has been duly acknowledged in the text and in a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any Institution.

Sim-nom ELISHA _____ _____

Signature Date

CERTIFICATION

This dissertation entitled "**EFFECTS OF SMOKING, FRYING AND FREEZING ON NUTRIENT COMPOSITION, MICROBIAL QUALITY AND SHELF LIFE OF *CLARIAS GARIEPINUS*BURCHELL 1822"** by ELISHA SIM-NOM meets the regulations governing the award of the degree of Master of Science, Educational Biology of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This Dissertation is dedicated to God Almighty who enabled me with grace, wisdom and knowledge to finish this project work.

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ABSTRACT

This study evaluate the effects of smoking, frying and freezing on the nutrient composition, microbial quality and shelf-life of *Clariasgariepinus*Burchell, 1822. A total of forty five (45) fresh African Catfish (*Clariasgariepinus*) with average body weight and length of 547.32 ±9.60 g and 40.31 ±5.56 cm respectively were purchased randomly from Zaria Dam (August, 2015). Eighteen samples each were subjected to smoking and frying, six samples for freezing and the remaining three samples as control. Analysis ofcrude protein, moisture, ash and fat/lipid contents of the fresh, smoked, fried and frozen fish were carried out according to the methods and procedures of the Association of Analytical Chemistry(AOAC). Data was subjected to one – way analysis of variance (ANOVA) at 5% level of significant to determine the differences in proximate composition of *Clariasgariepinus*processed using different methods.Fisher's least significant difference was used to separate differences in treatment means.Frying with vegetable oil produced significantly ($p<0.05$) highest crude protein, while frying with palm oil produced the least. The proximate composition of catfish smoked with charcoal showed that moisture contents ranged from 6.74-41.50%, other values were 58.50-93.27%, 25.66-59.44%, 4.00-16.75%, 2.10-18.74% and 13.17% for dry matter (DM), crude protein (CP), oil, ash and nitrogen free extracts (NFE) respectively. The effect of smoking with *Parkia*wood yielded proximate composition as moisture contents (7.57-19.11%), DM (83.97%), CP (39.66-68.13%), oil (5.36-36.45%), ash (3.15-13.64%) and NFE (5.64-29.05%). Smoking with *Anacardium*wood produced moisture content of 7.69-19.11%, DM (69.31.31%), CP (36.45-66.25%), oil (4.26-30.65%), ash (3.10-13.04%) and NFE (7.61-42.25%). The frozen method reduced the parameters as shown in the range of their values, DM (28.34-40.06%), CP (49.61-57.12%), oil (7.55-12.36%) ash (7.29-

13.85%) and NFE (21.48-35.16). Generally frying reduced the value of crude protein that ranged from 21.44-48.505 and increased NFE (11.38-66.52%) in frying with ground nuts oil. Similar figure was recorded in frying with vegetable oil with range of CP to be 21.44-46.54%, while NFE of 3.34-68.14% was obtained. The CP of frying with palm oil was found to be in a range of 19.25-56.69% and NFE of 10.87-68.14%. Smoking of all type in this study preserved dry matter and crude protein to a significant level, while freezing and frying decreased crude protein and increased nitrogen free extracts.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Fish is considered to be nutritionally superior to other sources of animal protein, containing most of the essential amino acids particularly lysine, leucine, valine, methionine and tryptophan and hence it is regarded as first class protein producer. This implies that fish possesses the requisite potentials of bridging the gap in the inadequate protein intake of most Nigerians when properly harnessed (Anyanwu, 2014).

Fish is an important source of both food and income to many people in developing countries. In Nigeria as much as 10% of the population, (about 14 million) people depend wholly or partly on the fisheries sector for their livelihood (Akinrotimi*et al.,* 2011).Fish is a highly nutritious food, containing high amounts of proteins with high biochemical value for humans. In addition, it is a very good source of polyunsaturated fatty acids (PUFA) known to be beneficial in preventing cardiovascular diseases, breast and colon cancer, psoriasis etc. Highly unsaturated fatty acids (HUFA) present in marine fish oil are medically proven to be beneficial against inflammatory disorders and ischaemic heart disease by modifying arachidonic acid/prostaglandin pathways. Fish also contain micronutrients such as iodine, selenium and fat-soluble vitamins (A and D) that have positive effects on human health. In many developing countries of the world, small fish are eaten whole and thus contribute calcium, phosphorus and iron to the human diet (Hassan, 2001). Fish and fish products play a significant role in the diets of the populations of West African Countries and constitute more than 60% of the total

proteinintake in the rural areas. It is also eaten as fresh, preserved or processed smoked and formsmuch- cherished delicacy that cuts across socio-economic, age, religious and educational barriers in Nigeria (Akintola*et al*., 2013).

Fish is consumed as food and is an important contributor to the national economy because it is readily available in most markets as fresh, smoked, dried, canned, chilled, frozen and fried. The fish nutrients play an important role in energy supply, repair of worn out tissues, synthesis of new tissues and the maintenance of several other functions in the body. It is the only source of cheaper protein with little or no religious taboo and has edge over beef or pork (Waindu and Jamala, 2013).

The processing of a fish inevitably entails a storage period for the finished product prior to marketing and consumption. Since fish are composed of perishable nutrients, storage period should be kept to a minimum with adequate storage conditions provided so as to prevent deteriorative changes occurring through oxidative damage and/or microbial, insect or rodent infestation. The most important environmental factors governing the storage or shelf life of fish are ambient temperature and humidity. These factors dictate the rate at which chemical changes take place (Daramola*et al.*, 2007).However, fish is an extreme perishable food after catch and therefore requires immediate and proper handling and good preservation to retain health (Akise*et al*., 2013).

The total fish demand for Nigeria based on the 2014 population estimate of 180million is 3.32million Metric tons. The domestic fish production from Aquaculture, Artisanal and Industrial fisheries for 2014 is 1.123million metric tons.Also in 2014, fisheries contributed 0.48% to the Agriculture Gross Domestic Product (GDP) and contribution of

Agriculture to Gross Domestic Product was 20.24% (FCWC, 2017). Regrettable, the total aggregate domestic fish supply from all sources (capture and cultured fisheries) is less than 0.7 million Metric tons per annum (Issa*et al*, 2014). Nigeria has to import about million Metric tons of fish annually valued at about $500 million to augment the short fall. This massive importation of frozen fish in the country has ranked Nigeria the largest importer of frozen fish in Africa (FMARD, 2011). It is projected that per capita consumption of fish would be 13.5kg from 2010 to 2015, while projected demand for fish would have increase from 1,430,000 tons to 2,175,000 tons in 2015, with the supply gap deficit of 144,752 tons (FMARD, 2011). The foregoing scenario is fact that the fish demands of Nigerians have not been met. Therefore, one is not surprised that Nigeria is highly deficient in animal protein security with the per capita consumption put at 9.3gram/day as against the 34gram/day minimum requirement for the growth and development of the body recommended by the Food and Agriculture Organisation (FAO) (Esobhawan*et al*, 2008). At this juncture, it becomes appropriate to ascertain the factors driving the demand for fish in the polity ostensibly to make recommendations for appropriate policy interventions. Such factors may be domiciled in the socio-economic cum cultural characteristics of the consumers or the macroeconomic milieu (Anyanwu, 2014).

Policies put in place by successive administrations to boost local production, through artisanal, industrial capture fisheries and aquaculture production, have fallen short of tackling this ugly trend that has continued to fritter away Nigeria's foreign exchange. Fisheries sub-sector analysts maintain that fish farmers and fisher folks have not been adequately motivated and assisted by the government to go all out to the field and put in

their best to pull the country out of dependency on Asian and other countries that flood Nigerian market with all sorts of frozen fish (Ahmed,2015).

Some of the imported fishes are said to be poisonous and pose a serious threat to health of Nigerian consumers, many of whom are not even aware of the status of the fishes they consume. Thus the importation of fish should be discouraged and local production encourage. Ahmed (2015) said that "bridging the fish demand and supply gap in Nigeria requires a lot of commitment from the government and other stakeholders". Proper fisheries policies, adequate laws and regulations, among others, must be put in place by the government to attract investors into the sub-sector. Investors want to be sure that their businesses are protected(Ahmed,2015).

The major components of fish are moisture, protein, and lipid with vitamins and minerals occurring in trace amounts (Ali, 2014). Generally, fish contains very little carbohydrate, while the moisture content is very high. In most fish species, moisture content is between 60-80%, protein between 15-26% and lipid 2-13% (Pearson & Cox, 1976). The lipid content of fish varies with species, age, nutrition, size, and season. Although fish is a good and alternative sources of some essential nutrients, cooking practices could cause modifications in proximate composition, fatty acids and amino acids, as well as changes in solubility and nutritional values (Ali, 2014).

1.2 Statement of Research Problem

The processing activities on fish do not only remove excess water, but affects the nutritional content of the fish. It has been observed that the intensity of heat during processing affects the fish protein concentration. Previous studies have shown some

endogenous pro-oxidants activities that lead to quality loss during frozen storage of fish (Ali, 2013). It has been observed that different processing methods have different effects on the organoleptic properties and the nutritional composition of fish due to heating, freezing and exposure to high concentration of salt which changes the chemical and physical concentration, leading to increase in digestibility and protein denaturation (Opara*et al*., 2013).

1.3 Justification

The usefulness of fish in alleviating malnutrition is well known in Nigeria and attempts must be made to increase the domestic fish production to meet demand.Fish is a highly perishable commodity, deterioration sets in some few hours after being caught depending on the species and the prevailing ambient temperature. This may render it unacceptable and unfit for human consumption. Proper preservation starts the moment it is harvested until it reaches the consumer's table. This will require stepping up the total catch through proper management of fishery resources and improving handling, preservation, processing and utilization of the catches to minimize losses from wastage (Waindu and Jamala, 2013).

In view of these facts, thisstudy was carried out to determine the effects of smoking, frying, and freezing on nutrient compositions, microbial quality and shelf-life of *Clariasgariepinus* so as to minimize the future post-harvest losses to the nearest possible, and also to provide traders and consumers with the information on the processing method with the longest shelf life and qualitative nutrients.

1.4 Aim and Objectives

The aim of this study was to evaluate the effects of smoking, frying and freezing on nutrient composition, microbial quality and shelf-life of *Clariasgariepinus*.

The specific objectives were to:

i. determine theeffects of processing methods on proximate composition of *Clariasgariepinus*.
ii. determine the shelf life of *Clariasgariepinus* from different processing methods.
iii. determine the microbial quality of *Clariasgariepinus* after processing.

1.5 Research Hypotheses

I. There is no significant differences on the nutrient composition of *Clariasgariepinus*after processing.
II. There is no significant differences in the shelf life of smoked, frozen and fried *Clariasgariepinus.*
III. There is no significant differences in the microbial quality of *Clariasgariepinus* after processing.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The African Catfish

2.1.1 Classification of *Clariasgariepinus*

African catfish are mentioned within traditional capture-based aquaculture (known as wheddos in Benin and Ghana and barochois in Mauritius) for centuries. Their culture in modern times follows a similar trend to that of tilapias: first domestication trials by the year 1950 and adoption of the North African catfish *Clariasgariepinus* as the most desirable catfish for aquaculture in the mid-1970s. However, under culture conditions, it is difficult for the fish to spawn spontaneously (FAO, 2006). The African Catfish *Clariasgariepinus*belongs to the family Clariidae (Air breathing catfishes), Order Siluriformes, Class Actinopterygii (ray-finned fishes), Sub Phylum Vertebrata, Phylum Chordata and Kingdom Animalia. The family Clariidae is divided into two genera viz: *Clarias*and *Heterobranchus*. There are over hundred species in this family Clariidae occurring naturally throughout most of Africa and the Southern half of Asia to Java and the Philippines (Obaroh*etal*., 2015).

2.1.2 Distribution of *Clariasgariepinus*

*Clariasgariepinus*is generally considered to be one of the most important tropical catfish species for aquaculture.It has an almost Pan-African distribution, ranging from the Nile to West Africa and from Algeria to Southern Africa. It also occurs in Asia Minor (Israel, Syria and South of Turkey) (FAO, 1996).*Clariasgariepinus*at various geographical locations bears different names. It is called *C. lazera*in Northern and Central Africa, *C.*

*senegalensis*in East Africa, *C. mosambicus*in West Africa and *C. gariepinus*in South Africa (Solomon and Zainab, 2017).*Clariasgariepinus* is commonly referred to as African Catfish, Sharp tooth Catfish, Catfish, Common Catfish, Mudfish, Barbel, Sharp toothed Catfish and North African catfish. In Africa, the *C. gariepinus* species is native to the following countries: Algeria; Angola; Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; The Democratic Republic of Congo; Egypt; Eritrea; Ethiopia; Ghana; Guinea; Israel; Jordan; Kenya; Libya; Malawi; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal; Somalia; South Africa; Sudan; Swaziland; Syrian Arab Republic; Tanzania, United Republic of Togo; Turkey; Uganda; Zambia and Zimbabwe (Au-ibar, 2015).

C.gariepinus is elongate with fairly long dorsal and anal fins. The dorsal fin has 61-80 soft rays and the anal fin has 45-65 soft rays. They have strong pectoral fins with spines that are serrated on the outer side. This species can attain sizes of up to 1.7 meters including the tail and can weigh up to 59 kg when fully grown. They possess nasal and maxillarybarbells and somewhat smallish eyes. Their colouring is dark grey or black dorsally and cream coloured ventrally. Adults possess a dark longitudinal lines on either side of the head; however, this is absent in young fish. Adult's heads are coarsely granulated, while the head is smooth in the young. The head is large, depressed, and heavily boned. The mouth is quite large and sub-terminal (Gunder, 2004).

In *C.gariepinus*, exchange of respiratory gases (i.e. oxygen and carbon dioxide) takes place through the gills. Like any other mudfish, it has accessory breathing (arborescent) organ which enables the fish not only to live in stagnant pools but to travel over damp ground. *Clariasgariepinus* differs from other catfishes in having an auxiliary breathing

organ in its special pockets, 16 attached to the second and fourth gill arches and are responsible for the ability of *Clariasgariepinus*to live out of water much longer than other catfishes (Solomon and Zainab, 2017).

C.gariepinus live in a variety of freshwater environments, including quiet waters like lakes, ponds, and pools. They are also very prominent in flowing rivers, rapids, and around dams. They are very adaptive to extreme environmental conditions and can live in pH range of 6.5-8.0. They are able to live in very turbid waters and can tolerate temperatures of 8-35 degrees Celsius. Their optimal temperature for growth is 28-30 degrees Celsius. They are bottom dwellers and do most of their feeding there. They are also obligate air breathers, which means they do spend some time on the surface. This species can live in very poorly oxygenated waters and is one of the last species to live in such an uninhabitable place. They are also able to secrete mucus to prevent drying and is able to burrow in the muddy substrate of a drying body of water (Gunder, 2004).

2.2 Catfish Nutrition

C. gariepinus are omnivores. They are not specific in their food requirements. They are known to feed on insects, planktons, snails, crabs, shrimps, and other invertebrates. They are also capable of eating dead animals, birds, reptiles, amphibians, small mammals, other fishes, eggs, and plant matter such as fruits and seeds. Because they are mobile on land, they are able to prey on terrestrial organisms. This species may also hunt in packs on occasion by herding and trapping smaller fish. They are also referred to as sharp tooth catfish because of fine, pointed bands of teeth (Gunder, 2004).

Growth, health and reproduction of fish is primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved. The major classes of nutrients are as follows:Fats and carbohydrate (energy source), Proteins, Vitamins and Minerals (Hasan, 2001).

2.2.1 Energy Requirement of catfish

Energy is one of the most important parts of the diet. Feeding standards for many animals are based on energy needs. Feed intake for catfish may be more a function of how much feed the catfish are allowed to have rather than energy concentration in the feed. Although catfish feed intake may not be strictly regulated by dietary energy, balance of dietary energy is important when formulating catfish feeds (Hassan, 2001). This is true mainly because lack of non -protein energy in the diet will result in the more expensive protein being used for energy. Also, if dietary energy is too high, catfish may not eat as much, resulting in fewer intakes of essential nutrients. Too high dietary energy/protein ratio may lead to higher body fat, which may reduce dressed yield and shorten shelf life of frozen products. Estimates have been made by measuring weight gain or protein gain of catfish fed diets with a known amount of energy. Energy requirements reported for catfish, which have generally been expressed as a ratio of digestible energy (DE) to crude protein (DE/P), range from 7.4 to 12 kilocalorie/gram (kcal/g). Based on current knowledge, a DE/P ratio of 8.5 to 9.5kcal/g is adequate for use in commercial catfish feeds. Increasing the DE/P ratio of catfish diets above this range may increase fat deposition and reduce processed yield, and if the energy value is too low the fish will

grow slowly. Carbohydrates and lipids (fats and oils) are the major energy sources for catfish (Robinson *et al*., 2006).

2.2.2 Carbohydrates Requirement of catfish

Carbohydrate is a cheap source of dietary energy in fish. Carbohydrates are important non-protein energy sources for fish and should be included in their diets at appropriate levels which maximizes the use of dietary protein for growth (Orire and Sadiku, 2014).Carbohydrates are the main form of energy stored in seeds, roots, and tubers. Carbohydrates have several functions in animals. But since animals can produce carbohydrates from lipid and protein, they do not need carbohydrates in the diet for normal growth and functions. Even though catfish do not need carbohydrates in their diet, catfish feeds contain considerable carbohydrates supplied from grain or grain by-products (such as corn grain, wheat grain, and wheat middling) that are rich in starch. Starch is not only an inexpensive energy source but also aids in feed manufacture. Atypical catfish feed contains 25 percent or more soluble (digestible) carbohydrates plus 3 to 6 percent more carbohydrates that are generally present as crude fibre (mainly cellulose). Catfish cannot digest crude fibre well, so it should be kept at low level as possible. Commercial catfish feeds typically contain less than 5 percent crude fibre (Robinson *et al*., 2006).The utilization of dietary carbohydrate has also been found to vary with the complexity or chemical structure of the carbohydrate source used (Hassan, 2001).

2.2.3 Lipids Requirement for catfish

Lipids and fats both serve as source of essential fatty acids (EFA) and energy thus sparing protein as a diet component. They also act as carriers of fat soluble vitamins.

Recent studies on EFA in fish suggest that their fats requirements may differ from species to species. Apart from carbohydrates, fish can use large quantities of fat as an energy source, with consequent sparing of protein in the ration. Fats are most efficient calories source because of the energy density of the diet component. It has been shown that unsaturated fatty acids are the best form of fatty acids for nutritional requirement of fish(Udiba*et al*., 2014).

Lipids (fats and oils) are easily digested source of concentrated energy, having more than twice as much energy as an equal amount of carbohydrates. They play several important roles in an animal's metabolism, including supplying essential fatty acids (EFA), helping absorb fat-soluble vitamins, and other important functions.Lipids in the diet may also increase food intake. Lipids stored in body tissues affect the flavor of the flesh. The type and amount of lipid in catfish diets is based on EFA requirements, constraints of feed manufacture, and quality of fish flesh desired. A small amount of lipid should be included to supply EFA. Catfish apparently require 0.5 percent to 0.75 percent omega-3 fatty acids in the diet. Aside from meeting EFA requirements, lipid is not necessarily required as a nutrient in the diet of catfish. But since it is a concentrated source of energy and is less expensive than protein, some fat should be included in catfish diets. Too much dietary lipid, though, may result in too much fat deposited in the body. This may affect processed yield, product quality, and storage of processed products. Also, high-lipid feeds may be more difficult to pellet, but if needed, supplemental lipid can be sprayed onto the finished feed pellets. Lipid levels in commercial feeds for table-size catfish rarely exceed 5 to 6 percent (Robinson *et al*., 2006).Lipids are primarily included in formulated diet to maximize their protein sparing. There is convincing evidence that the degree of

unsaturation does not appreciably affect digestibility or utilization of fats and oils as energy sources for cold water or warm water fish. Dietary lipids provide essential fatty acids (polyunsaturated fatty acids, PUFAs) that fish, like all animals, cannot synthesize but require for the maintenance of cellular function (Hasan, 2001).

2.2.4 Protein and Amino Acids Requirement of catfish

Proteins are large molecule of compounds consisting of multiple combinations of amino-acids joined together by peptide linkage formed from Sulphur bonds, Hydrogen bonds and Vander waals forces. All fish species require the same amino-acids which are Arginine, Histidine, Isoleucine, Lysine, Valine, Therconine, Methionine, Phenylalanine and Tryptophan. These amino acids must be present in their diet since the fish species cannot synthesize those (Udiba*et al*., 2014).

Protein comprises about 70 percent of the dry weight of fish muscle. A continual supply of protein is needed throughout life for maintenance and growth. Catfish, like other animals, need nitrogen and certain amino acids rather than protein as such. Usually the most economical source of these elements is a mixture of proteins in feedstuffs. Using protein for energy is expensive, so catfish feeds should be balanced to ensure adequate levels of nonspecific nitrogen, amino acids, and non-protein energy are supplied in the right amounts. Various efforts have been made to establish the crude protein and amino acid requirement of *C. gariepinus*(Ayinla and Akande,1988) recommended 35% and 40% crude protein (CP) for raising table size and brood acid (EAA) required by warm water fish species only 3 EAAS studied have been documented and these are arginine, methionine and lysine (Solomon and Zainab, 2017). Catfish fry and small fingerlings

require diets with more protein. Fry diets used in the hatchery should contain 45 to 50 percent protein, and fingerlings (less than 20 lbs. /1,000) should be fed a 35 percent protein diet. Catfish feeds generally contain a mixture of plant and animal proteins, but amino acid requirements of catfish can be met with a mixture of plant proteins alone. Major protein sources used in catfish feeds include soya bean meal, cottonseed meal, meat bone/blood meal, and fish meal. Although meat, bone and blood meals are good sources ofprotein for catfish, beef products are not recommended using in catfish feeds because of the possibilitythat it may contain pathogensrelated toCreutzfeldtJakob disease commonly known as mad cow disease (Robinson *et al*., 2006).

2.2.5 Vitamins Requirement of catfish

Vitamins vary greatly in structure and function. They are generally defined as organic compounds andanimals require themin small amounts in their diets for normal growth, health, and reproduction. Some vitamins may be made in the body and thus are not required in the diet. The amounts and quality of vitamins catfish need have been fairly well determined in laboratories and pond studies. Catfish feeds are generally supplemented with a vitamin premix that contains enough of all essential vitamins to meet the requirement and make up for losses from feed processing and storage (Robinson *et al*., 2006). Vitamins are needed for normal growth, maintenance and reproduction of fishes. Thiamin, Riboflavin, folic acid, pyridoxine, choline, ascorbic acid, vitamin B12, Nicotine acid, pantothenic acid are all essential vitamins required for growth of all temperate fishes. It is reported that thiamin deficient fish soon developed paralysis, while growth retardation and cataracts develop on fish deficient in riboflavin diets. Fish

deficient in pyridoxines have been found to exhibit violent muscular contraction and later died (Udiba*et al*., 2014).

2.2.6 Minerals Requirements of catfish

Minerals available in feed ingredients are not always sufficient to meet the fish's requirements. Some of the minerals may be leached during the processing of the food. Moreover, many of the feed ingredients may be rich in particular minerals and deficient in others, or only partially available to the animal consumers (Hassan, 2001). Minerals, like vitamins occur in most natural diets in sufficient quantities to satisfy the metabolic requirements of fish. Some mineral elements are known to be required in trace form, while others are required in fairly large quantities in animals. Fishes depend partly on minerals absorbed from the surrounding water through the gills, intestine and skin while some are obtained from the diets. About twenty inorganic elements are required to maintain the structure and metabolic functions of vertebrates (Olubanwo,2011). Of these twenty inorganic elements, six are of importance namely; calcium, chlorine, sodium, magnesium, phosphorus and potassium while the remaining are needed in minute quantities in feed. In catfish farming, salt regulation is of special significance since freshwater fish are likely to lose ions to greatly hypotonic environment and thus suffer from dehydration. The opposite is the case with saltwater fish. Salt regulating mechanisms are highly developed in fish especially those that migrate from freshwater to saltwater and vice versa(FAO, 2008).

Apparently catfish need the same minerals for metabolism and bone development that other animals need. Catfish also require minerals for a balance between body fluids and their environment. Although mineral studies with fish are difficult to do, the mineral

amounts needed is known, and the signs of mineral deficiency are also known. Phosphorus is particularly important in fish feeds because fish require a fairly large amount of it. Feedstuffs, especially those from plants, are poor sources of phosphorus, and fish do not get enough phosphorus from pond water. As a result, catfish feeds are usually supplemented with phosphorus. Dicalcium and defluorinated phosphates are commonly used as phosphorus supplements in catfish feeds.Catfish feeds are typically supplemented with a trace mineral premix with enough of all essential trace minerals (minerals required at very low levels) to meet or exceed dietary requirements of catfish. A trace mineral premix may not be needed in catfish feeds that contain 4 percent or more animal protein (Robinson *et al*., 2006).

2.3 The Concept of Processing and Preservation in the fisheries industry

The fish processing industry is very widespread and quite varied in terms of types of operation, scales of production and outputs. In general, fish processing operations are located close to the commercial fishing areas. However, in some cases catches may be transported over long distances or exported for processing (Sinha, 2011).The fish processor has the numerous tasks of ensuring that fish and fish products meet the set standards of the consumers. Thus, the processor must understand the science and technology of the processes and must be able to modify them to meet the needs of the consumers (Eyo,2001).

The purpose of processing and preserving fish is to get fish to an ultimate consumer in good, usable condition. The steps necessary to accomplish this begin before the fishing expedition starts, and do not end until the fish is eaten or processed into oil, meal, or a

feed.Immediately the fish dies it remains in first class quality for only a short while. Within this period, the flesh is firm and tender, the skin is bright with firm scales. The gills are bright red exuding fresh odor and the eyes are bulging or convex and iridescent. After a few hours depending on the species and the prevailing ambient temperature the flesh begins to soften and later become flabby, the skin loses its sheen with loose scales, the gills change colour from bright red to pink and later greenish with ammoniac odour, the eyes become sunken in the cranium. The fish has now lost its acceptability and is rejected by consumers as unfit for human consumption (Eyo, 1997). Therefore, the key to delivering a high quality product is close attention to small details throughout the entire process preparation, catching, landing, handling, storage, and transport.Fish that becomes spoiled or rotten is obviously unusable. Fish that is poorly cared for may not be so obviously bad, but it loses value because of off-flavors, mushy texture, or bad colour that discourage a potential consumer from buying. If customers have bought one bad fish, they probably won't buy another. On the other hand, if you consistently deliver good quality at a fair price, people will become loyal customers. The aim of fish processing and preservation is to slow down or prevent enzymatic, bacterial, and chemical deterioration, and to maintain the fish flesh in a condition as near as possible to that of the live fish (Sinha, 2011).

2.3.1 Primary Processing

Fish processing has the following functions namely; preservation of the product form, converting the material to desirable form, maintaining product quality, assuring consumer's safety, and full utilization of the raw material (Eyo, 1997). Fresh fish are

highly perishable and start to spoil as soon as they are landed. Concern for quality should begin on board the vessels. The first consideration should be to bring the fish on aboard alive and in a good condition.Fish should only come in contact with clean surfaces to keep bacterial contamination low.Fish should be handled with care, kicking, or dumping the fish will increase the rate of spoilage. For high quality, fish should be chilled as quickly as possible to 0°C (Eyo, 1997). Before fish are landed, hot decks should be cooled with clean seawater. Because high temperature is the single biggest cause of quality loss, fish should be moved promptly from the deck to cool storage (Sinha, 2011).

2.3.2 Secondary Processing

The purpose of secondary processing is to convert the raw fish into a form that is acceptable to the consumers and that has a longer shelf- life. However, to ensure a high-quality finished product, it is necessary to begin with high-quality raw product (Sinha, 2011).

2.4 Fish Handling

2.4.1 Fish Capture

Fish is a major source of protein and its harvesting, handling, processing and distribution provide livelihood for millions of people. Appropriate processing of fish enables maximal use of raw material and production of value-added products which is obviously the basis of processing profitability. The quality of the freshly caught fish and its usefulness for further utilization in processing is affected by the fish capture method. Unsuitable fishing

method does not only cause mechanical damage to the fish, but also creates stress and the conditions which accelerate fish deterioration after death (Tawari and Abowei, 2011). Fresh fish after capture should be properly handled if the quality and shelf life are to be improved reasonably. One of such good handling practices is to ensure that, capture live fish are not allowed to struggle and die of asphyxia or oxygen starvation. Struggling after capture, except in the case of the catfishes, will hasten spoilage *post-mortem* by accelerating chemical reactions in the flesh of the fish. This will reduce the period the fish will remain in *rigor* or stiffened; thereby, accelerating bacteria attack and spoilage. Catfishes are known to remain alive for a long time after capture and should not be stunned (Ayuba and Omeji, 2006).

2.4.2 Fish killing

Handling live African catfish is easy because, as long as the skin remains wet, they can stay alive for many days out of water (FAO, 2006). After harvesting, catfish should be demobilized by piercing the brain with a sharp object or by giving a blow to the head to ensure instant death. Fresh fish deteriorates very rapidly. It is necessary to ensure that fish and fish products get to the consumer in acceptable quality. The initial handling of freshly caught fish prior to processing must fulfil certain conditions to maintain the acceptable quality (Tawari and Abowei, 2011).It is common knowledge that if fish are kept clean and are at low temperature, growth of bacteria, consequently spoilage is kept at minimum. There are numerous requirements, which include adequate supply of clean water. The water should preferably be chlorinated. Chlorinated clean water will remove over 90% of the bacteria invading fish surfaces. Fish preparation surfaces, equipment and tools should depend largely on the materials from which they are made. Metal working

surfaces, holding equipment, and tools are preferred since they are easily cleaned using soaps and detergents. Fish are easily bruised (Davies, 2006).

2.4.3 Fish spoilage

Spoilage and freshness are the two qualities that have to be clearly defined. A fresh product is defined as the one whose original characters remain unchanged. Spoilage therefore is the indicative of post-harvest change. This change may be graded as the change from absolute freshness to limits of acceptability to unacceptability. Spoilage is usually accompanied by change in physical characteristics. Change in colour, odour, texture, colour of eyes, colour of gills and softness of the muscle are some of the characteristics observed in spoiled fish. Spoilage is caused by the action of enzymes, bacteria and chemicals present in the fish. In addition, the following factors contribute to spoilage of fish (Prabjeet, *et al*., 2017). The quality of capture is important in determining the rate of spoilage. Notably are the fish health status, the presence of parasites, bruises and wounds on the skin and the mode by which the fish was captured. The caught fish quality depends on the handling and preservation of the fish received from the hands of the fishers after capture. The handling and the preservation practices after capture affect the degree of spoilage of the fish (Tawari and Abowei, 2011). Locally, fish spoilage has been known to be influenced to a large extent by high ambient temperatures, considerable distances from landing sites as well as poor and inadequate infrastructure for post-harvest processing and landing. Investigations into such losses revealed sorting from artisanal fishing nets, limitation of processing equipment, and absence of cold storage facilities on small fishing craft and poor water transport as prevalent factors (Ali, 2013).

In most cases there are critical microbiological factors that influence fish spoilage such as water, temperature, acidity, oxygen and inhibitory substances. Since the minimum water activity requirements of normal bacteria, yeast and mould are 10, 91, 0.88, respectivelywhile micro-organisms can cause spoilage at temperature range of 10 ºC and 70 ºC in terms of acidity when the pH is neutral it favours the growth of bacteria, slight acidity favours yeast and acidity mould can tolerate. The oxygen exerts selectivity effect on microbial population either aerobic or anaerobic bacteria (Ugwu and Mgbenka, 2006). These are some of the factors that could be considered: activity of micro-organisms such as bacteria, moulds, and yeasts; deterioration through chemical processes such as break down of oils and fats (described as rancidity), and enzymes activity; attack by insects such as blow flies, beetles and various scavenging animals such vermins (Haruna, 2003); contamination from people (germs on skin cuts on hands) soil, dust, sewage, surface water manure and also by poor handling, use of poorly clean apparatus and contamination after a preservation treatment has been carried out example fish kept in dirty basket (Waidu and Jamala, 2013).

Immediately fish dies, it remains in first class quality only for a short time. Spoilage soon sets in which is occasioned by an increase in the ambient temperature that triggers favourable conditions for microorganisms to thrive. Microorganisms' contamination of fresh fish is a major cause of spoilage. It is common knowledge that if fish are kept clean and is at low temperature, growth of bacteria; consequently, spoilage is kept at minimum. Other factors are the poikilothermic nature of fish, a high *post-mortem* pH in the flesh, and the presence of non-protein nitrogen (NPN) in large quantities and Tri-methylamine oxide (TMAO) The poikilothermic nature of fish selects bacteria that can thrive in a wide

range of temperatures. The presence of NPN and TMAO on decomposition of fish flesh, give rise to the off-flavours typically found in spoilt fish. The autolytic enzymes such as protease acts on the fish muscle causing softening of fish flesh and off-flavours. These enzymes result in the breakdown of Adenosine Diphosphate (ADP), Adenosine Monophosphate (AMP), hypoxanthine and others amines. Microorganisms such as bacteria also act on the dead fish, producing volatile bases such as Trimethylamine (TMA) and Hydrogen sulphide (H_2S). Oxidation of lipids is associated with a decrease in triacylglycerol's and phospholids and an increase in fatty acids and often results in a product with off flavors (rancid) which may not be appealing to many consumers (Abolagba and Igbinevbo, 2010). It is therefore, important to understand the causes of spoilage and how to prevent these causes so as to minimize losses. Since fish are the most important animal protein in the diet of many people in Nigeria. Spoilage of fish may take place before, during, or after processing. The sooner any preventive measures are taken after capture of fish, the greater the chance of reducing post-harvest losses so as to increase fish availability to meet the demand of the growing population. These post-harvest losses exacerbate the problem of insufficient supply of fish in Nigeria (Waindu and Jamala, 2013).

2.4.4 Post-Harvest losses

Fish is a perishable food which needs processing and preservation. It is well known and documented that a large percentage of the fish caught in the developing countries are lost through poor handling resulting to an estimated loss of about 4.2 million tons as annual global fish post-harvest losses (PHL). In Nigeria, the estimated post-harvest losses are at

about 50% and an estimated fish losses in Kanji Lake area is about 256,008 naira in 1996 and 163,604 naira in 2001 (Oladele and Odedeji, 2008).

Post-harvest losses in fish products are a major setback of the Nigeria fish industry especially at the artisanal level. Whereas artisanal fisheries are responsible for over 60% of the total domestic production annually, the magnitude of losses in this sector has been estimated at 30%-50% of total catches. This range of figure is alarming when one considers the fact that Nigeria presently meets only 60% of her total fish need and spendsforeign exchange in importing frozen and canned fish to supplement the deficit. The artisanal fisheries of Nigeria are endemic to these post-harvest losses (Bolorunduro*et al*., 2005).

Post-harvest losses are defined as a reduction in quantity, or quality or monetary value of fish in the supply chain. Post- harvest loss of fish occurs in all fisheries or value-chains, to varying extents. Losses typically result in lost income and losses in the availability of fish as food hence they represent a major food security concern in Africa, where many people are food insecure. (Davide, 2015).

2.4.5 Categories of Post-Harvest Losses

Post-Harvest losses can be categorized as follows: Physical Loss which refers to losses of fish either completely (gross physical losses) or by loss of some pieces (net physical losses). Gross physical losses occur from dumping of low value by-catch at sea.This seldom happens in the artisanal fishery where most of the by- catches are utilized, whole spoilt fish which are not edible and have to be thrown away also fall into this category. Net physical losses occur as a result of nutrient loss through poor handling and

processing. This includes dried fish in which much of the flesh has been consumed by maggots or beetles in storage, and fragmented fish which fall into the fire and cannot be retrieved during smoking (Eyo, 1997). Economic loss occur due to downgrading of spoilt fish originally meant for human consumption into fish meal. Usually partial spoilage may not affect the value of the fish but as spoilage increases the value drops. High quality fish which should have been exported but downgraded for domestic consumption also fall into this group. Nutritional Losses: Nutritional loss is described as the loss of nutritional value of fish due to spoilage or exposure to high temperature during smoking causing damage to part of the protein fraction such as lysine.

Producers such as fishermen and processors lose income when they have to sell their fish for a low price due to the effects of spoilage or damage. In cases of severe spoilage or if processed fish is infested by insects, then fish may become un-saleable and the result is a physical loss where no income is generated, but importantly there is no contribution to food security(Davide, 2015).

Globally fish losses are estimated to be ten to twelve million tonnes per year, accounting for around ten percent of the total production of capture fisheries and aquaculture.The most common causes of losses are found in inadequate handling and processing methods, lack of knowledge and skill amongst producers, as well as poor access to infrastructure, equipment and services such as water, ice, electricity, roads and credit. Other underlying causes of loss are also lack of or poor market information, weak and unsupportive policy and socio-cultural factors. Whilst there are often estimates of loss in terms of percent or monetary value, these are often generalisations of complex and dynamic situations. Basing intervention decisions on these assumptions is a risk, so in order to reduce losses

we first of all require a more detailed picture of the who, what, where, why, how and when of post-harvest fish losses. For example, losses are often seasonal, occurring during times of glut catches or the rainy season when traditional processing methods are less effective.Losses are also associated with certain species of fish or types of fishing or processing method. They may also be occurring in particular types of location e.g. remote areas where services and infrastructure are poor. In addition, coping strategies to control losses may already exist and could form the basis of effective interventions (Davide, 2015).

For the fact that post-harvest spoilage has hindered the even supply of fish protein to Nigerians, the need to preserve fish for better shelf-life, good flavour as well as creation of employment opportunity became imperative, being that fish is one of the most perishable food staples. Fish spoils very quickly because of intrinsic and extrinsic factors. The high ambient temperature in the tropics hastens fish spoilage by accelerating the activities of bacteria enzymes and chemical oxidation of fat in fresh (Waindu and Jamala, 2013).

There are numerous requirements of preventing fishspoilage which include adequate supply of clean water. The water should preferably be chlorinated. Chlorinated clean water will remove over 90% of the bacteria invading fish surfaces. Fish preparation surfaces, equipment and tools should depend largely on the materials from which they are made. Metal work surfaces, holding equipment, and tools are preferred since they are easily cleaned using soaps and detergents. Since fish are easily bruised, it is mandatory that they should not be walked over, instead, they should be kept in boxes, or baskets at chilled temperature shielded from direct sunlight to minimize microbial spoilage. Fish

deterioratesvery rapidly in the tropics especially when they have been gutted or filleted due to the high temperature and the increased exposed surfaces.

In all the processes, a large quantity of water is required. The use of chlorinated water enhances product quality. The recommended chlorine dose is 0.3mg/L for washing fish. Utensils and premise clean up may require water with chlorine concentration of 25mg/L. Personal hygiene of the staff is very important in fish handling and preparation. Adequate clean up and washrooms must be provided. Fish processing areas must be washed everyday using detergents.

As soon as, fish are harvested from ponds, processing and packing should effectively be carried out in one location. Let the floor be smooth, non-slippery, well drained and water proof. This makes for easy cleaning. The doors and windows should be fly screened with efficient ventilation. Aluminum alloy equipment is preferred. Electrical installations should be well insulated. Adequate water supply via high-pressure hoses for wash down is necessary (Tawari and Abowei, 2011).

A number of processing techniques are in operation in Nigeria, this includes: Smoking, Freezing, Frying, chilling, Salting, Canning and Drying. However, Smoking, Freezing and Frying are the most popular methods of fish processing. Though processing provides a higher production, less waste and low production costs. Processing has been known to affect the chemical composition of the fish processed. Most processing methods serve not only to conserve the fish but also to alter their nutrient levels either positively or negatively (Ali, 2013).

2.5 Fish Preservation

Fish is a product that needs proper handling and processing in order to preserve nutrients and its functional components that promotes good health (Agbolagba and Igbinevbo, 2010). The processing and preservation of fresh fish are of outmost importance to prevent economic losses since fish is highly susceptible to deterioration immediately after harvest (Okonta and Ekelemu, 2005).If fish is not sold fresh, preservation methods should be applied to extend shelf-life. These include smoking, freezing, drying and frying etc. Efficient preparation of fish is important when top quality, maximum yield and highest possible profits are to be achieved).The development of fishing machinery and techniques that can be employed for effective fish handling, harvesting, processing and storage can never be over-emphasized especially in the age when aquaculture development is fast gathering momentum in Nigeria. Fish processing is to give the product a form which is attractive to the consumers. The characteristics of processed stored fish should ensure full health safety of the product, proper sanitary condition as well as rendering it impossible for the development of harmful micro-organism and toxins (Tawari and Abowei, 2011).

High quality products which are safe and satisfactory to the consumers can be achieved by compliance with standard processing parameters from the start of the operation to the storage and distribution of the final products. With improved technologies, fresh fish can be stored for the desired period needed without any significant loss of quality. Presently in Nigeria, the mechanization level of fish processing is low which results from the overall limited production, seasonal availability of fish, poor information dissemination of the available improved technology to processors, and lack of inexpensive equipment adaptable for processing and storage of various fish species.Tawari (2006) reported 10-

15% losses during fish drying and 12-20% during storage in Niger Delta. Eyo (2001) reported a loss of 35% in Kanji Lake which was estimated to be about N80 million in 1995. The problem of high incidence of losses has been recognized as a major impediment to realization of the Nigeria government goal of increasing the contribution of the fish industry sector to overall national economy. Preservation is carried out for the purpose of extending the shelf life of fish (Tawari and Abowei, 2011).

2.6 Fish Smoking

Smoking is one of the oldest methods of preserving fish. Long before there were refrigerators and freezers, our fishing ancestors learned to use a combination of salt and smoke to keep fish from spoiling (Sinha,2011). Smoked fish products have long shelf life, which has been attributed to the drying and cooking effects. When wood and sawdust are burnt, smoke is produced as a result of incomplete combustion. The smoke produced depends on the amount of air available and the quality of wood or sawdust. Soft woods produce a lot of smoke, which may lead to blacking of the finished products. Wood smoke is a mixture of complex chemical product gases, vapour and volatile substances. The volatile substances are absorbed on the wet surfaces of fish during the smoking and produce the characteristic aroma(Tawari and Abowei, 2011).

Smoking is meant to preserve fish by reducing moisture content; however, the traditional smoking process is associated with unavoidable losses of nutrients. Before smoking, fish products are placed on racks on or in the kiln and allowed to drip for several hours, which results in some nutrients being lost in the exudates and the process also fosters microbial growth that induces proteolysis. During the smoking process, fat and more water drips

from the fish resulting in physical loss of lipids (including essential fatty acids) and micronutrients. Smoking is a preferred method of preservation because it dries the fish, melts down some fat, and reduces microbial growth. When this is achieved, smoking is expected to extend the shelf-life of most fish products to two weeks. With the growing fuel wood crisis, fish products are not being smoked long enough to reduce moisture content to the recommended 10% or lower. Therefore, partially or unevenly smoked fish are susceptible to enzymatic lipid oxidation and protein hydrolysis, which results in losses of essential lipids, protein, and other nutrients involved in these chemical reactions (Kabahenda*et al*., 2009).

Fish smoking is a traditional method of processing globally; it accounts for about 3% of the world's catch and also increases the fish shelf-life. The flesh of smoked fish is delicate, succulent, and delicious and can be readily consumed without further processing (Agbabiaka*et al*., 2012).However, smoking is the affordable and most widely used method for fish preservation in Ghana, Nigeria and other West African countries. It has been reported that up to 70% of the total fish catch in several communities in the third world are smoked (Felix, 2014).

However, smoking may present some potential health issues to smoked food consumers; the process of smoking fish or meat involves the use of sodium, sometimes through curing before smoking. Fish, for example, is usually marinated in brine or packed with salt and can trigger high blood pressure in high doses. In addition, improper fish curing before smoking presents the risk of food poisoning that can lead to bacterial infection, listeriosis in the consumer and bacterial or fungal growth on the fish. However, it has been noted that if properly prepared and eaten in moderation, the highlighted problems

may be mitigated (Felix, 2014).Fish smoking is particularly relevant in the artisanal fisheries sector in that it prolongs the shelf-life of the fish, enhances flavour and increases utilization of the fish in addition to reducing waste when catches are good, as well as increasing protein availability to rural people (Ayeloja*et al*., 2011).

2.6.1 Types of Fish Smoking Processes

In fish, two types of smoking processes are common use. The cold smoking in which the temperature of the smoke does not exceed 30°C and hot smoking during which the fish is properly smoked with the temperature reaching 120°C or so while the center of the fish may be at 60°C (Eyo, 2001). Cold smoking is practiced in places where alternative means of preserving the fish such as refrigeration is available. Cold smoking is primarily done to improve the flavour of the fish and retain its nutritive value. Cold smoked fish is not well cooked, has shorter shelf-life and easily infested by micro-organisms such as bacteria and moulds if not properly stored in a refrigerator. Moisture retention is very high and may be in the order of 35-45% (Eyo, 2001).

Hot smoking is the traditional method of fish preservation in the tropics. Fish is smoked until cooked in order to obtain a product with extended shelf-life, since alternative preservation method such as refrigeration are absent in remote villages where most fish processing takes place. The primary aim of hot smoking is to preserve the product, flavour and colour arising as a results of the preservation function. Therefore, in an attempt to produce a product with a low moisture of less than 30% required, to make the product safe from mould and bacteria infestation during short term storage at ambient temperature, the fish may be dried so as to become brittle or charred (Eyo, 2001).

2.6.2 Methods of Fish Smoking

Fish smoking in the tropics is conducted in smokehouses and smoking ovens or kilns. The design of this working equipment varies from place to place. The smoking methods can be classified into traditional, improved traditional and mechanical smoking kilns. (Eyo, 2001)

2.6.3 Effect of Smoking on Nutritive Value of fish

Although consumers are generally attracted by the flavors of smoked fish, its nutritive value is of paramount importance since every consumer would want to obtain good quality protein from fish. Most of the work on the nutritional value of smoked fish has centered on lysine –an essential amino acid which is limiting in cereals and root crops which are the stable food of most inhabitants of tropical countries. Lysine is the most sensitive basic amino acid to heat damage- the loss of lysine being proportional to the temperature and duration of smoking (Eyo, 2001).

The loss in available lysine may vary from 6-33% to 53-56% during hot smoking. Other basic amino acids were reduced by 6.6% on the surface but remain unchanged at the center. The loss of lysine is partly attributed to high temperature effect as a result of Maillard reaction. This reaction involves the amino groupof amino acids with sugars (usually glucose or ribose) and carbonyls.Losses in other amino acids such as arginine and histidine and a decline in net protein utilization (NPU) have been observed in smoked fish. Smoking of bacon was found to result in some loss of thiamine (2-25%) with negligible loss in niacin and riboflavin. It has also been reported that even in the absence of the Maillard reaction, heating alone is sufficient to render lysine unavailable. A

number of chemical reaction may take place during heat treatment including decomposition, dehydration of serine and threonine, loss of Sulphur from cysteine, oxidation of cysteine and methionine, cyclization of glutamic and aspartic acids and threonine. However, over 75% of the protein and more than 50% of the vitamins and minerals are still retained in smoked fish. The loss of water increases the concentration of nutrients and the denaturation effect of smoking increases the digestibility of protein and hence the availability of some essential amino acids (Eyo, 2001).

As it is frequently seen in fish markets, properly smoked fish products are dark brown in colour and are mostly near perfectly dried. This ensures that the shelf life is prolonged and the products get to the consumer in relatively good state. Kumolu-Johnson *et al*. (2010) carried out a work on the effect of smoking on the nutritional qualities and shelf life of *C.gariepinus* and reported that the highest moisture content (81.03 ± 10.69%) was recorded in fresh *C.gariepinus* while the lowest (10.86 ± 2.33%) was found in smoked fish. There was significant ($p < 0.05$) reduction in moisture content when the fish was hot smoked. This is due to loss in moisture during hot smoking.The percentage ash, crude protein and fat contents in smoked*C.gariepinus* were significantly ($p<0.05$) higher than in the fresh samples. Also, the highest value of Crude Protein was (62.14 ± 6.67%) in smoked fish, and was (14.23 ± 4.13) in fresh fish; Fat Content was (23.90 ± 7.51%) in Smoked fish, and was (3.44 ± 0.69) in fresh fish and the Ash content was (3.10 ± 0.53%) in smoked fishand was (1.30 ± 0.23) in fresh fish.The total coliform count (Log10 Cfu/g) of skin was (4.593), gill (4.428) of fresh samples and the total coliform count of freshly smoked*C. gariepinus*was 2.744 (Salan*et al*., 2006).

2.7 Fish freezing

Freezing is the method most people choose for preserving fresh fish and other seafood products. However, this preservation technique is effective only if the product is handled in such a way that its quality is kept near its peak freshness (Roxie, 2013).Fish freezing is a method in which the product is brought into contact with refrigerated air or refrigerated surface in a compartment. As heat is removed from the fish, its temperature falls steadily until the fish begins to freeze. During freezing the temperature falls below that of ice (0°C) Microbial activity is slowed down and as the temperature goes further down to -30°C most bacteria may die out. Freezing enhances the microbial stability of fish and extends its shelf life (Eyo, 2001). Fish that has to be preserved by freezing should be cleaned and packed before *rigor mortis* sets in for easy operation and maximum use of freezing space (Tawari and Abowei, 2011). Pure water freezes at 0ºC. Fish contains about 80% water, salts and minerals. As would be expected therefore, fish can be frozen at temperatures lower than 0ºC. As the water freezes out, the concentration of salts and chemicals increase thereby lowering the freezing temperature. At about -5ºC, up to 20% of water in fish is still unfrozen. The freezing stage in fish has been divided into three. The first stage includes the period when the temperature falls rapidly to about -1ºC. At -1ºC, the temperature remains fairly constant and up to 75% of the water freezes. This is the thermal arrest stage of which there is no change in the temperature. In the third stage, the temperature begins to drop and most of the remaining water freezes (Bolaji, 2005).

In the process of freezing, heat is transferred from the fish to be frozen to some surrounding of adjacent material. It is necessary that a sufficiently cold surrounding must be supplied to effect this change (Tawari and Abowei, 2011).

Presently, the only means of preserving fish in its original fresh state is by freezing. The aim of freezing of food items is to combine shelf life extension with maintenance of sensory and nutritional characteristics. It is reported that at low temperatures (that is, below -10 °C), bacterial action will be hindered by the freezing process (Felix, 2014).Freezing also enhances fish marketing in distant places, away from the fishing port. Freezing therefore facilitates long term storage, marketing and distribution of fish and fish products (Eyo, 2001).

The research conducted by Ali (2013) on the impact of freezing on nutritional composition of some less known selected fish showed that amounts of protein, fat, moisture and ash in all fish species decreased with the freezing process. The processing method, frozen storage altered the percentage fat and protein of the fishes. Although freezing as a common practice fishing industry,it has been known to preserve the quality for an extended time, and offer several advantages such as minimum deterioration in products, colour, flavour and texture.

2.7.1 Effect of Freezing on Nutritive Value of fish

Previous studies carried out by Felix, (2014) on the effect of smoking and freezing on the nutritive value of African mudcatfish showed thatthe moisture was (8.640 ± 0.101), ash was (8.220 ± 0.249) and carbohydrate was (21.900 ± 0.210) contents in the frozen fish samples were not significantly different ($p>0.05$) from the 8.629 ± 0.196, 8.192 ± 0.272 and 22.990 ± 0.454, respectively recorded in the fresh fish (control).While the frozen fish samples have significantly lower protein (24.160 ± 0.562) and crude fiber (0.980 ± 0.094) contents than the (34.277 ± 0.547) and (1.330 ± 0.11) obtained in the control. The lipid

content (36.410 ± 0.400) in the frozen fish was statistically higher than the fresh fish (33.324 ± 0.227) was statistically higher ($p<0.05$) than the fresh fish (33.324 ± 0.227).

2.8 Frying and its Effect on Nutritive value of fish

Deep frying (also referred to as deep fat frying) is a cooking method in which fish is submerged in hot fat, most commonly oil, rather than the shallow oil used in conventional frying, done in a frying pan. Normally, a deep fryer or chip pan is used for this; industrially, a pressure fryer or vacuum fryer may be used. Deep frying may also be performed using oil that is heated in a pot. Deep frying is classified as hot-fat cooking method. Typically, deep frying cooks fish quickly: all sides of fish is cooked simultaneously as oil has a high rate of heat conduction (Wikipedia, 2017).

Deep frying is popular worldwide, with deep-fried foods accounting for a large portion of global caloric consumption Frying is one of the most common practice in food preparation in Nigeria. It gives unique organoleptic characteristics to foods such as flavour, texture and appearance, which can improve the palatability of foods. During frying, water in food is replaced by the frying oil and as a consequence, the oil becomes an important component of the fried food. However, different oils are used to prepare foods (Mehdi and Mohammad, 2012). However, frying is one of the fastest and simplest methods of fish cooking. The deep – frying can be done in oil in a frying pan on hot flame with occasional turning in order to achieve even frying(Ayeloja*et al*., 2013). Deep frying fish is defined as a process where fish is completely submerged in hot oil at temperatures typically between 350 °F (177 °C) and 375 °F (191 °C). Since frying involves a very high temperature, It degrades nutrients through hydrolysis and oxidation

of the fatty acids. The breakdown products can give rise to good flavour and taste. However, cooking methods are very important for nutritive value of fish. The food nutritive value can be affected by deep-frying. Similarly, nutritive value of fish can be changed by deep-frying (Rahman *et al*., 2012).

Deep frying has the advantage of reducing fat. However, there is concern that deep frying may reduce the nutritive value of the oil and the fried products, especially since oil is subjected to high temperatures and is also reused many times. In general, fish oils, because of their high content of unsaturated fatty acids, are highly susceptible to oxidative reaction which leads to rancidity. Fish oil is also rich in vitamin A, ß-carotene and α-tocopherol and is less prone to oxidation. It is not clear whether deep frying reduces both the levels of -3 fatty acids however, literature indicates that deep frying may have more effect on fatty acid functionality when compared to other direct heat treatment methods such as boiling and baking(Kabahenda*et al*., 2009).

Despite the above advantages, the various processing methods (Smoking, Freezing and Frying) have been known to affect the chemical composition of the processed fish. Apart from conserving the fish, most processing methods also alter their nutrient levels and shelf-life either positively or negatively. Therefore, knowledge of the nutrient compositions of freshwater fish and the relationship between their chemical composition, fish value and stability while being processed into acceptable preserved products is of significant practical interest (Ekpenyong and Ibok, 2012).It has been observed that different processing methods have different effects on the nutritional composition of fish due to heating and freezing which changes the chemical and physical concentration, leading to increase in digestibility and protein denaturation (Opara*et al*., 2013).

2.9 Shelf-Life of Fish

Shelf life of food is defined as the maximum length of time a given product is fit for human consumption. For fish, shelf life is the time from when it is harvested from the water until it is no longer fit to eat. In marketing, the shelf life of fresh and frozen fish is a very important consideration. Knowing the remaining shelf life allows the processor and retailer to plan the length of time a product can be held, allowing control of their market. Adding one or two days to the shelf life allows the market to get top dollar and assure repeat sales. Temperature and handling practices are the most important factors in determining the shelf life of all species of fish. If the fish product is handled carefully, the temperature at which it is held controls its useful life. Temperature will control the rate of bacterial spoilage and enzyme breakdown. An indisputable fact is that the higher the temperature the faster fish spoils (John, 1995).

2.9.1 Factors Affecting the Rate of Spoilage in Fish

The main factors that affect the rate of spoilage in chilled fish include:Temperature, Physical damage and Intrinsic factors (FAO, 1995).

2.9.1.1 *Temperature*

It is well known that both enzymatic and microbiological activities are greatly influenced by temperature. However, in the temperature range from 0 to 25°C, microbiological activity is relatively more important, and temperature changes have greater impact on microbiological growth than on enzymatic activity. Many bacteria are unable to grow at temperatures below 10°C and even psychotropic organisms grow very slowly, and sometimes with extended lag phases, when temperatures approach 0°C.At 0°C the growth

rate is less than one-tenth of the rate at the optimum growth temperature. Microbial activity is responsible for spoilage of most fresh fish products. The shelf life of fish products, therefore, is markedly extended when products are stored at low temperatures. It is well known that high temperatures increase the rate of fish spoilage and low temperatures slow it down. Therefore, if the temperature of fresh fish is low, then quality is lost slowly. The faster a lower temperature is attained during fish chilling, the more effectively the spoilage activity is inhibited. Generally, the rate at which fish loses quality when stored in ice (0 °C) is used as the baseline when comparisons are made regarding shelf-life at different storage temperatures (FAO, 1995). The relationship between the shelf-life of fish at 0 °C and at t °C is known as the relative rate of spoilage at t °C (RRS) and is defined below:

$$\text{Relative rate of spoilage at t °C} = \frac{\textbf{keeping time at 0°C}}{\textbf{keeping ti me at t °C}}$$

2.9.1.2 *Physical damage*

Fish is soft and easily damaged, therefore rough handling and bruising result in contamination of fish flesh with bacteria that allow releases of enzymes and speeding up the rate of spoilage. In addition, careless handling can burst the guts and spread the contents into the fish flesh (FAO, 1995).

2.9.1.3 *Intrinsic factors*

The intrinsic factors affecting the spoilage rate of chilled fish could be at slow or fast rate depending on the type, shape, and size, fat content in the flesh and skin characteristics.

E.g. Flat, large, lean and thick fish species, intrinsic factors are slow while round, small, fatty and thin fish species, intrinsic factors are fast (FAO, 1995).

2.9.2 Shelf life Prediction

Although the spoilage of fish undoubtedly involves a number of interactions among many of a variety of reactants that may be present in them, a significant amount of data in the literature appear to support this dissertation that one of the reactions must be limiting with the consequence that it controls the spoilage rate. While it is generally accepted that the spoilage rate is dependent of the activity of the spoilage bacteria (the activity of bacteria is generally expressed as a function of the integral of the area under the bacterial growth curve).That is, the spoilage rate depends on the number ofspoilage bacteria until a level of activity has been reached such that the spoilage rate is no longer affected by an increase in the bacterial numbers (Louis and Stanley, 1975).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

This study was conducted from August to November, 2015(a period 3 month)s in the Department of Biology, Ahmadu Bello University, Zaria, Kaduna State.

3.2 Materials and Preparation of Samples

A total of forty- five (45) fresh African Catfish(*C.gariepinus*)were purchased fromZaria dam and brought to the Department of Biology for measurement as follows:Average body weight and total length of the fishes were measured to the nearest gram and cm using weighing balance and meter rule respectively. The fish were gutted and washed thoroughly with clean water to remove slime and blood after which were transferred into a basket for proper draining of water before subjecting them to the various processing procedures; smoking, frying and freezing. (18) Sampleseach were subjected to smoking and frying processing procedures, (6) samples were subjected to freezing and the remaining three (3) were used as control.

3.3 Smoking Process

Hot smoking means curing fish by smoking at a temperature of 70-80°C and such fish do not require further cooking before consumption. It provides a longer shelf life because the fish is smoked until dry (Sinha, 2011). Smokingwas carried out using *Parkiabiglobosa*wood (SPW), *Anacardiumoccidentale*wood(SAW), these woods were

gotten from botanical garden, Department of Biology, ABU Zaria and charcoal of different wood types(SCDW)purchased fromSamaru marketin Zaria.

Six samples each of the gutted fish were hot smoked with *Parkia* for 72 hours and *Anacardium* wood for 60 hoursin a traditional drum smoking kiln(drum-type-smoking kiln with a singlesmoking rack) The drum type kiln was fabricated from a 44- gallon drum (fig.3.4) by simply opening the top end of the drum and passing iron rods at about 20cm below the top, then smoking racks of wire mesh are placed on the iron rods. At the opposite end of thedrum a 30-cm square opening was created to form the stokehole. Fish were placed on the smoking rack and fire from below,the fish are covered with iron sheet to conserve the smoke within the drum (Eyo,2001).The remaining 6 samples were smoked with charcoal in a charcoal pot with smoking racks of wire mesh placed on top of thecharcoal pot, then the fish were arranged on the smoking racks and covered with iron sheet to conserve the smoke as smoking takes placefor a period of 48 hours.



Plate I: Traditional drum kiln

During all the smoking processes, turning over of the fish samples was done at interval of 30 minutes to achieve uniform smoking. The temperature in the smoking chambers ranged from 60- 80^0C. After smoking, the products were removed from the kiln and allowed to cool down to ambient temperature, then packed in a wire net basket and padlocked (Salan*et al*., 2006) and stored at room temperature (Bilgin*et al*., 2008) for a period of 2, 4,6 ,8,10 and 12 weeks. Proximate analysis was carried out for the 18 smoked samples bi- weekly to determine the effect of smokingon the nutrient compositions and its shelf-life.

3.4 Freezing Process

Freezing is the removal of heat, and fish from which heat is removed falls in temperature(Sinha, 2011).As heat is removed from the fish, its temperature fall steadily until the fish begin to freeze and falls below that of ice(0°C) to the recommended storage temperature(-30°C) in order to extend its shelf life(Eyo,2001).Each fish samples was put in a transparent leather to prevent it from freezing(FZ) together and then stored in a functional deep freezer(domestic/household freezer)in the Department of Biology for 2,4,6,8,10, and 12 weeks with temperature range -10°C to-34°C. The samples were further analyzed every two weeks each to ascertain the effect of freezing on the nutrient composition of frozen fish.

3.5 Frying Process

Eighteen gutted fish samples, 6 each were fried in hot palm oil(FPO), vegetable oil(FVO) and groundnut oil(FGO) respectively (purchased from Samaru Market). They were deep fried in a frying pan separately on a hot flameof firewood with occasional turning in

order to achieve even frying. Frying with palm oil was achieved within 60 minutes, vegetableoil within 55 minutes and groundnut oil within 50 minutes at temperature of 110°C - 120ºC.

The products were put into a basket and allowed to cool down to ambient temperature and then packed and arranged in a wire net baskets and stored at room temperature (Salan*et al*., 2006). The 18 fried fish samples were analyzed every week to determine the effect of frying on the nutrient composition and its shelf-life.

3.6 Proximate Analysis

The determination of the crude protein, moisture, ash and lipid content of the fresh, smoked, fried and frozen fish was carried out in the Department of Animal Science, Faculty of Agriculture, ABU,Zaria according to the AOAC (2000) methods.

3.6.1 Protein Content Determination

The protein content was obtained through the determination of total nitrogen by micro Kjeldahl's method as described by Pearson and then multiplied by 6.25 to get the crude protein value (Pearson, 1970) as follows:

3.6.1.1 Digestion

Half gram (0.5g) of well ground sample was weighed; a little scoop of digestion catalyst was added and 20 ml of conc. Sulphuric acid was also added slowly. After the reaction had subsided, the digestion flask was placed on a digester and it was digested for 2 h at 80°C until itbecame clear. It was then made up to 50 ml mark after cooling in ameasuring cylinder.

3.6.1.2 Distillation

Fifty milliliter (50 ml) of boric acid was measured (plus indicator) intoa 200 ml conical flask. The flask was placed under the receiving tube of the distillation unit in a way that the end of the tube is below boric acid level.

Twenty milliliter (20 ml) of the sample was measured into Kjeldahl digestion flask and 50 ml of 40% NaOH was added carefully without shaking the flask.

3.6.1.3 Titration

The distillate was titrated with standard hydrochloric acid until the end point was reached that is when there is a clear fluid color change.

$$\% \text{ Nitrogen} = \frac{\text{Titre value x Acid concentration x 0.014x Dilution Factorx100}}{\text{Weight of Sample}}$$

% Crude Protein = % Nitrogen × 6.25

3.6.2 Moisture Content Determination

The moisture content was determined according to AOAC (2000). The empty dish was dried with lid in the oven at 105° C and then transferred to the desiccator to cool and then weighed. The fish sample in the dish was weighed and placed in the oven to dry for 3hr at 105°C.After drying, it was transferred to the desiccator to cool to room temperature and reweighed. The lost in moisture content was calculated as follows:

$$\text{Moisture}(\%) = \frac{W_1 - W_2}{W_1} \text{ x}100$$

Where: W_1= weight(g) of sample before drying

W_2= weight (g) of sample after drying

3.6.4 Ash Content Determination

The ash content was determined by heating the samples to a temperature of 550^0C to ensure that

Impurities on the surface of the crucible are burned off, the residue isequivalent to the ash content.

It was allowed to cool in the desiccator for 30 mins and weighed.About 5g of thesample was weighed into the crucible and heated overnight at 550°over low Bunsen flame with lid half covered.Aftercomplete heating, the lid is placed to prevent loss of fluffy ash and cooled down in the desiccator.The ash was weighed with the crucible and lid till the sample turns gray**.**

$$\text{Ash}(\%) = \frac{\text{weight of ash}}{\text{weight of sample}}\ x100$$

3.6.5 Lipid Content Determination

The bottle and the lid were placed in the incubator at 105°C overnight. About 3-5g of sample was weighed into paper filter wrapped and thentakento the extraction thimbleand transferred into the Soxhlet. The sample was heated for about 14hr (heat rate of 150drop/min) andthen the solvent was evaporated by using the vacuum condenser and the bottle incubated at 80-90°Cuntil the solvent was completely evaporated and the bottle was completely dry. After drying, the bottle wastransferred with partially covered lid to the desiccator to cool and then the bottle was reweighed and its driedcontent.

$$\text{Fat}(\%) = \frac{\text{weight of fat}}{\text{weight of sample}}\ x100$$

3.7 Microbiological Analysis

3.7.1 Isolation of bacterial isolates from fish samples

Isolation of bacterial isolates from fish samples of the three different methods of processing; Smoking, Frying and Frozen storage was doneat the end of 12 weeks of storage. One gram of each of the samples(smoked, fried and frozen samples) was cut out and weighed using a top loading balance (Metler,PM4800).Each weighed sample was transferred into a blender containing 9.0 ml of sterile deionized water. The samples werehomogenized to prepare the stock suspension. One ml of the stock was serially transferred to six (6) test tubes each containing nine(9.0) ml diluents, one at a time of repeated succession up to the sixth test tube to obtain 10^{-7} dilution (Akise*et al,* 2013).

Dilutions of 10^{-2} ,10^{-4} and 10^{-5} were selected for each of the fish treatments. A pour plate method was used for each of the serially selected diluted sample and wasalso prepared by using approximately 20.0ml of nutrient agar, amended with anti-fungal agent, fulcin (500mg in 200ml of H_2O used at a ratio of 2-3 drops in 20ml of agar) and 5.0ml of dilution suspension from each of the fish samples were duplicated and incubated at room temperature (28 ±2ºC) for 24 hrs (Akise*et al.*, 2013).

3.7.2 Identification of Bacterial Isolates

All isolates were characterized and identified using morphological and biochemical tests such as gram stain, methyl red, Voges-proskaur, indole, oxidase, catalase, coagulase, hydrogen sulphide, motility, Gelatin liquefaction, citrate and sugar fermentation test as described by Cowan and Steel (1970).

3.8 Data Analyses

Data was subjected to one–way analysis of variance (ANOVA) at 5% level of significance to determine the differences in proximate composition of processed fish and frozen fish. Fisher's least significant difference was used to separate significantly different treatment means.

CHAPTER FOUR

4.0 RESULTS

4.1 Proximate Composition of preserved and variously processed*Clarias gariepinus*

The effect of processing methods on proximate compositions of *C. gariepinus* is shown in Table 4.1. Moisture content was significantly ($p<0.05$) high in frozen (68.00%) fish than other methods of preservation. It was followed by fish SCDW (43.63%), FGO (38.80%), FPO (34.09%), control (24.18%), SAW (23.50%), while fish SPW (17.29%) had the least moisture contents after processing. There was no significant difference ($p>0.05$) in dry matter of processed *Clarias*SPW(82.71%) and FVO (83.78%). Similarly, dry matter of fish processed using control (75.82%) and SAW (82.71%) did not differ significantly ($p>0.05$) but were higher than fish FPO (65.91%), SCDW (56.37%) and FZ (32.00%). The Control (48.78%) had the best crude protein but decreased significantly ($p<0.05$) in other methods in this order: *C. gariepinus* FVO (41.38%) > SPW (39.65%) > SAW>(34.98%) > SCDW (24.35%) > FGO (23.60%) > FPO (18.62%) > FZ (11.68%). There was no significant difference ($p>0.05$) in lipid contents of the processed fish SPW (35.50%) and FVO (34.55%) methods but were significantly higher than fish FPO (33.42%), SAW (30.04%), FGO (21.83%), SCDW (16.05%), FZ (13.33%), while control (8.25%) had the least lipid value. Ash content of *Clarias* from control group (11.52%) was the highest, while FZ method (0.04%) was the least. There was no significant difference in ash contents among fish SPW (3.03%), SAW (3.18%), FPO (3.10%), FVO (2.58%) and FGO (3.10%) but were significantly higher than fish SCDW (2.23%). Control (31.54%) had better NFE compared to the experimental groups. Nitrogen free

extracts of processed fish was better in fish SCDW (14.36%), FZ method (6.60%) had the least.

Table 4.1: Proximate Composition of *Clariasgariepinus*from different processing and a preservative method

Samples	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.42^{e}	75.82±0.37^{b}	48.78±1.99^{a}	8.25±0.60^{f}	11.52±0.38^{a}	31.54±0.87^{a}
SPW	17.29±1.28^{f}	82.71±1.29^{a}	39.65±0.51^{b}	35.50±0.56^{a}	3.03±0.06^{b}	5.48±0.12^{de}
SAW	23.50±0.70^{e}	76.50±0.70^{b}	34.98±0.77^{c}	30.04±0.39^{b}	3.18±0.11^{b}	7.24±0.20^{d}
SCDW	43.63±1.39^{b}	56.37±1.39^{e}	24.35±0.71^{d}	16.05±0.91^{d}	2.23±0.21^{c}	14.36±0.54^{b}
FGO	38.80±0.49^{c}	61.20±0.49^{d}	23.60±0.60^{d}	21.83±0.60^{c}	3.10±0.36^{b}	12.32±0.51^{c}
FPO	34.09±0.75^{d}	65.91±0.90^{c}	18.62±0.77^{e}	33.42±0.59^{a}	3.10±0.26^{b}	11.61±1.11^{c}
FVO	16.22±0.75^{f}	83.78±0.75^{a}	41.38±0.71^{b}	34.55±0.89^{a}	2.58±0.21^{bc}	3.78±0.24^{e}
FZ	68.00±0.58^{a}	32.00±0.58^{f}	11.68±0.65^{f}	13.33±0.88^{e}	0.04±0.02^{d}	6.60±0.72^{d}

Means with the same superscript along columns are not significantly ($p>0.05$) different

Key:

Control= Fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbodydrates

SPW= Smoked with *Parkia* wood

SAW= Smoked with *Anacardium* wood

SCDW = Smoked with charcoal of different wood types

FGO = Fried with groundnut oil

FPO = Fried with palm oil

FVO = Fried with vegetable oil

FZ = Frozen fish

4.2 ProximateComposition of stored*C. gariepinus* smoked with charcoal

The effect of smoking with charcoal on the shelf life of *C. gariepinus* is shown in Table 4.2. Moisture contents was significantly ($p<0.05$) highest in 1st period (41.50%) of processing than control (24.18%). It decreased significantly ($p<0.05$) to (17.44%) in 4th period of processing. This was followed by 3rd period (16.90%) in which it was significantly ($p<0.05$) higher than (14.54%) recorded in 2nd period. In the same way, 6th week of collection was significantly ($p<0.05$) higher than 5th period (6.74%). The percentage dry matter was significantly ($p<0.05$) higher in the 5th period (93.27%) of processing than the 84.89% recordedin 6th period·There was no significant ($p>0.05$) difference between 3rd (83.10%) and 4th (82.56%) periods dry matter, but reduced significantly ($p<0.05$) at 1st period (58.50%). Crude protein was significantly ($p<0.05$) higher at 2nd period than all the experimental processing periods and control.The value in 3rd period (56.90%) was also high compared to 6th period (50.87%) followed by 4th (49.38%) and the least was in 5th (46.19%). Lipid contents of Catfish was significantly ($p<0.05$) higher in 1st period with (16.75%). The value dropped to (9.86%) in 6th period, but it was significantly ($p<0.05$) higher than control (8.21%) and the latter was incomparable to 4th period (7.69%). The oil level in 3rd periodwas significantly ($p<0.05$) higher than 2nd and 5th period with (4.00%) and (4.88%) respectively. There was increase in ash content at period 5 with (18.74%) compared to 6th and control with (11.62%) each.

Table 4.2:Proximate Composition of stored*C.gariepinus* Smoked with Charcoal

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01[b]	75.82±0.01	48.96±0.01	8.21±0.01	11.62±0.00	31.21±0.01
2nd Week	41.50±0.01[a]	58.50±0.01	25.66±0.01	16.75±0.01	2.10±0.01	13.97±0.01
4th Week	14.54±0.01[e]	85.46±0.01	59.44±0.01	4.00±0.01	9.48±0.01	27.08±0.01
6th Week	16.90±0.01[d]	83.10±0.01	56.90±0.01	6.83±0.02	9.43±0.05	26.84±0.04
8th Week	17.44±0.02	82.56±0.02	49.38±0.01	7.69±0.02	9.76±0.01	33.17±0.02
10th Week	6.74±0.02	93.27±0.00	46.19±0.01	4.88±1.00	18.74±0.01	29.19±0.00
12th Week	13.80±0.06	84.89±0.61	50.87±0.01	9.86±0.01	11.62±0.01	27.65±0.02
Mean	19.30±2.29	80.52±2.28	48.20±2.27	8.32±0.88	10.39±1.01	27.02±1.28

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

The ash content at 4th period (9.76%) reduced, but it was significantly ($p<0.05$) higher than 2nd and 3rd periods having (9.48%) and (9.43%) accordingly and the least was in 1st period (2.10%). There was significant ($p<0.05$) NFE of the processing periods. Higher value was found in 4th period (33.17%) followed by control (31.21%). There was little drop in NFE to (29.19%) at 5th period but it was significantly ($p<0.05$) higher than the one obtained at 6th period (27.65%) and (27.08%) at 2nd period followed by 3rd period (26.84%) and the least was found in 1st period (13.97%).

4.3 Proximate Composition of stored *C. gariepinus* smoked with *Parkia biglobosa*

There was significant ($p<0.05$) difference in moisture contents between control (24.18%) and the smoked fish using *Parkiabiglobosa*(Table 4.3). The 3rd period (19.11%) recorded the highest significant ($p<0.05$) moisture contents followed by 2nd (16.03%). 1st (15.04%), 4th (14.49%), 6th (13.88%) periods and least was in 5th (7.57%). Dry matter increased significantly ($p<0.05$) in 5th period (92.43%) than all the experimental processing period and control (75.82%). It was followed by 5th period which decreased significantly ($p<0.05$) to (86.12%) then 4th, 1st, 2nd and 3rd with (85.54%), (84.96%), (83.97%) and (80.89%) respectively. The percentage crude protein was significantly ($p<0.05$) highest 4th period (68.81%) compared to control (48.96%) and the experimental processing periods. It was also significant ($p<0.05$) in 5th (60.81%) followed by 2nd (52.19%), 3rd (51.75%) 6th (51.04%) and the lowest was found in 1st (39.66%). Oil contents differed significantly ($p<0.05$) with processing period. At 5th period (36.45%) the oil value was the highest followed by 6th (9.78%), control (8.21%), 4th (6.89%),

3^{rd}(5.56%) and the least was recorded in 2^{nd} (5.36%), respectively and 5^{th} (5.37%) in which the latter did not differ significantly ($p<0.05$) from each other.

Table 4.3: Proximate Compositions of stored *C.gariepinus*Smoked with *Parkiabiglobosa*

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01	75.82±0.01	48.96±0.01	8.21±0.01	11.62±0.00	31.21±0.01
2nd Week	15.04±0.02	84.96±0.02	39.66±0.01	36.45±0.01	3.15±0.01	5.64±0.01
4th Week	16.03±0.01	83.97±0.01	52.19±0.01	5.36±0.01	13.33±0.01	29.12±0.01
6th Week	19.11±0.01	80.89±0.01	51.75±0.01	5.56±0.01	13.64±0.01	29.05±0.01
8th Week	14.49±0.05	85.54±0.02	68.13±0.01	6.89±0.01	9.17±0.01	15.81±0.01
10thWeek	7.57±0.01	92.43±0.01	60.81±0.01	5.37±0.01	15.74±0.1	18.08±0.01
12thWeek	13.88±0.01	86.12±0.01	51.04±0.02	9.78±0.02	11.80±0.01	27.37±0.01
Mean	15.76±1.05	84.25±1.05	53.22±1.87	11.09±2.34	11.21±0.85	22.331.95

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

At 5th period (15.74%) there was significant amount of ash compared to control (11.62%) and other processing period. The decrease in the ash contents was as follows: 3rd (13.64%) > 2nd (13.33%) > 6th (11.80%) > 4th (9.17%) > 1st (3.15%). Control (31.21%) produced significant ($p<0.05$) amount of NFE compared to the processing methods. The amount of NFE was higher in 2nd (2912%) and was significantly ($p<0.05$) higher than 3rd (29.05%); 6th (27.37%).It was similarly higher than 5th (18.08%). The same trend was found between 4th (15.81%) and 1st(5.64%), respectively

4.4 Proximate Composition of stored *C. gariepinus* smoked with *Anacardium occidentale*

Table 4.4 shows the effect of smoking with *Anacardiumoccidentale*on the proximate compositions of catfish. There was significant ($p<0.05$) difference in moisture contents between control and processed catfish. The amount of moisture was significantly ($p<0.05$) higher in 4th period than all the processing periods and control (24.18%); similarly significant ($p<0.05$) difference was observed in this order of decrease: 2nd (24.61%), 3rd (24.08%), 1st (22.18%), 6th (15.81%) periods and the lowest observed in 5thperiods(7.69%). Dry matter differed significantly ($p<0.05$) between control (75.82%) and processing period. It was significantly ($p<0.05$) higher in 5th (92.31%) than 6th (84.19%); Similar trend was recorded between 1st (77.85%) and 3rd (75.92%) as well as 2nd (75.39%) and 4th (68.69%) periods. Crude protein differed significantly ($p<0.05$) between all the processing periods and control (48.96%). The protein level was higher in 3rd period (66.25%) and it was followed by (55.31%) recorded in 5th period. similarly, period 6th and 4th differed significantly ($p<0.05$) with (54.81%) and (53.44%), respectively, while 2nd period (48.31%) and 1st (36.45%) also differed significantly ($p<0.05$).

Table 4.4: Proximate Composition of stored *Clariasgariepinus*Smoked with *Anacardiumoccidentale*

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01	75.82±0.01	48.96±0.01	8.21±0.01	11.62±0.00	31.21±0.01
2nd Week	22.15±0.01	77.85±0.01	36.45±0.01	30.65±0.01	3.10±0.01	7.61±0.01
4th Week	24.61±0.01	75.39±0.01	48.31±0.03	4.44±0.02	5.00±0.02	42.25±0.03
6th Week	24.08±0.01	75.92±0.01	66.25±0.01	4.26±0.01	4.96±0.01	24.53±0.01
8th Week	31.31±0.01	68.69±0.01	53.44±0.02	6.55±0.01	10.13±0.02	29.88±0.01
10thWeek	7.69±0.01	92.31±0.01	55.31±0.01	5.26±0.01	13.04±0.01	26.39±0.01
12thWeek	15.81±0.01	84.19±0.01	54.81±0.01	10.72±0.01	10.63±0.01	23.84±0.02
Mean	21.40±1.57	78.60±1.57	51.93±1.87	10.01±1.994	8.35±0.81	26.53±2.15

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

There was high quantity of oil in 1st period (30.65%) and which was followed by (10.72%), (8.21%), (6.55%), (5.26%), (4.44%) and (4.26%) in 6th, control, 4th, 5th, 2nd and 3rd periods, respectively. The ash contents was significantly ($p<0.05$) higher in 5th (13.04%) compared to control (11.62%) and the latter was significantly ($p<0.05$) higher than 6th (10.63%)and 4th (10.13%) respectively. The ash value further dropped to (5.00%), (4.96%) and (3.10%) in 2nd, 3rd and 1st accordingly. The NFE was significantly ($p<0.05$) higher 2nd period (42.25%) and the lowest was in 1st period (7.61%) of processing. Others reduced significantly ($p<0.05$) from control (31.2%), 4th (29.88%), 5th (26.39%), 3rd (24.53%) to 23.84% in 6th period.

4.5 Proximate Composition on shelf life of Catfish subjected to freezing

There was significant ($p<0.05$) difference between moisture content of control and samples that were frozen (Table 4.5). There was significant increase in moisture level at 5th (71.66%) followed by 6th period (70.13%); in the way, 4th period (70.05%) was significantly ($p<0.05$) higher than 2nd period (69.17%) and it was the same pattern observed between 3rd and 1st with (68.42%) and (59.94%) respectively. The amount of dry matter was low as high moisture content was recorded in the experimental samples except in control (75.82%) where dry matter was high. At 1st period (40.06%) was significantly ($p<0.05$) higher than 3rd period (31.58%). Further significant ($p<0.05$) reductions in this order: 2nd (30.83%) > 4th (29.95%) > 6th (29.87%) > 5th (28.34%) were recorded. The crude protein of the experimental samples was better than the control (48.96%). Significant ($p<0.05$) amount of crude protein was recorded at 5th period (57.12%), while the lowest was at 1st (49.61%). Others differed significantly ($p<0.05$) in

this order of crude protein decrease: 4^{th} (56.31%) 3^{rd} (52.44%) > 6^{th} (50.47%) > 2^{nd} (50.00%).

Table 4.5: Proximate Composition of *Clariasgariepinus*frozen for different durations

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01	75.82±0.01	48.96±0.01	8.21±0.01	11.62±0.00	31.21±0.01
2nd Week	59.94±0.04	40.06±0.04	49.61±0.02	7.88±0.01	10.69±0.15	31.82±0.03
4th Week	69.17±0.01	30.83±0.01	50.00±0.01	7.55±0.01	7.29±0.01	35.16±0.01
6th Week	68.42±0.01	31.58±0.01	52.44±0.01	8.62±0.01	8.36±0.01	30.58±0.01
8th Week	70.05±0.02	29.95±0.02	56.31±0.01	8.16±0.01	7.89±0.02	27.64±0.01
10thWeek	71.66±0.01	28.34±0.01	57.12±0.02	7.56±0.01	13.85±0.01	21.48±0.01
12thWeek	70.13±0.01	29.87±0.01	50.47±0.04	12.36±0.01	11.78±0.01	25.42±0.01
Mean	61.93±3.54	38.06±3.54	52.13±0.69	8.62±0.35	10.21±0.01	29.04±0.94

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrate

Oil value of catfish was significantly ($p<0.05$) different in all the samples including control. The variation decreased in this order: 6^{th} (12.36%) > 3^{rd} (8.62%) > control (8.21%) > 4^{th} (8.16%) > 1^{st} (7.88%) > 2^{nd} (7.55%) > 5^{th} (7.56%). Ash value was low in some samples, but they differed significantly ($p<0.05$) from each other and the control. It was significantly ($p<0.05$) higher in 5^{th} period (13.85%) compared to 6^{th} (11.78%). Similarly, control ash value was higher than 1^{st} (10.69%); the same observation was made between 3^{rd} (8.36%), 4^{th} (7.89%) and 2^{nd} (7.29%). The NFE value was lower than the one obtained from control (31.21%) except in experimental samples 1^{st} and 2^{nd}. It was significantly ($p<0.05$) higher in 2^{nd} period (35.16%) of processing than 1^{st} (31.82%). Further significant ($p<0.05$) reduction in NFE was recorded from 3^{rd} (30.58%) to 21.48% at 5^{th} period which was the lowest.

4.6 Proximate Composition ofstored *C. gariepinus*Fried with Groundnut Oil

Table 4.6shows the effect of frying with groundnut oil on the proximate contents of *C.gariepinus*. There was significant ($p<0.05$) difference in proximate compositions of *C. gariepinus* fried with groundnut oil kept for various storage periods. There was no significant ($p>0.05$) difference between moisture contents of 1^{st} (37.87%) and 2^{nd} (37.90%) periods; similarly, there was no significant ($p>0.05$) difference between control (24.18%) and 3^{rd} period (24.15%), but differ significantly ($p<0.05$) from 5^{th} (22.58%) and 4^{th} (22.60%), while 6^{th} period (16.58%) recorded the least moisture contents. Dry matter at 6^{th} period (83.42%) was significantly ($p<0.05$) higher than all the experimental processing periods and the control. There was no significant ($p>0.05$) different between 4^{th} and 5^{th} periods having (77.19%) each; similarly, there was no significant ($p>0.05$) difference between dry matter of control (75.82%) and 3^{rd} period (75.85%), but they were

significantly ($p<0.05$) higher than 1st and 2nd periods with (62.16%) and (62.13%) respectively.

Table 4.6: Proximate Composition of stored *Clariasgariepinus*Fried with Groundnuts Oil

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01 □	75.82±0.01 □	48.96±0.01 □	8.21±0.01□	11.62±0.01 □	31.21±0.01 □
1st Week	37.87±0.04 □	62.16±0.03 □	24.79±0.01 □	23.00±0.01 □	2.90±0.01□	11.38±0.01 □
2nd Week	37.90±0.01 □	62.13±0.03 □	24.79±0.01 □	23.00±0.01 □	2.90±0.01□	11.38±0.01 □
3rd Week	24.15±0.01 □	75.85±0.01 □	48.50±0.01 □	7.84±0.01□	4.46±0.01□	39.20±0.01 □
4th Week	22.60±0.21 □	77.19±0.01 □	42.76±0.01 □	7.54±0.01□	4.35±0.01□	4.35±0.01□
5th Week	22.58±0.23 □	77.19±0.01 □	21.44±0.01 □	7.69±0.01□	4.35±0.02□	66.52±0.01 □
6th Week	16.58±0.01 □	83.42±0.01 □	43.08±0.22 □	5.77±0.01□	5.26±0.01□	45.66±0.01 □
Mean	26.55±1.69	73.40±1.68	36.33±11.51	11.86±1.58	5.12±0.62	29.96±4.64

Means with the same superscript along the column are not significantly ($p>0.05$) 0different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

The percentage crude protein was significantly ($p<0.05$) higher than the experimental periods. Higher value of CP was recorded in 3rd period (48.50%) followed by 6th with (43.08%). The CP values in 1st (24.79%), 2nd (24.79%) and 4th (42.76%) were significantly ($p<0.05$) higher than 5th period (21.44%). The oil content was significantly ($p<0.05$) higher in 1st and 2nd periods with oil value of (23.00%) each. Control (8.21%) differ significantly ($p<0.05$) from 3rd period (7.84%) followed by 5th (7.69%), 4th (7.54%) and least was obtained in 6th (5.77%). All the experimental processing periods were significantly ($p<0.05$) lower than control (11.62%). The ash value in 6th period (5.26%) was significantly ($p<0.05$) higher than the 3rd period (4.46%). At 4th and 5th periods, the ash contents did not differ significantly ($p>0.05$) from each other, but varied significantly ($p<0.05$) from 1st and 2nd periods. The % NFE was significantly ($p<0.05$) higher in 5th period (66.52%), while the lowest was in 4th (4.35%). Other periods decreased in this order: 6th (45.66%) > 3rd (39.20%) > control (31.21%) > 1st = 2nd = 11.38%.

4.7 Proximate Composition of stored*C. gariepinus* fried with vegetable oil

The effect of frying with vegetable oil on proximate composition of *C.gariepinus* is shown in Table 4.7. There was significant ($p<0.05$) difference in moisture contents in all the periods of sample analysis. Moisture content was significantly ($p<0.05$) higher in 4th collection (31.24%) followed by 6th (18.52%), 5th (18.18%), 1st (14.18%), 2nd (12.90%) and the least was in 3rd (11.98%). The dry matter was higher in 3rd (88.02%) and the lowest was found in 4th (68.02%), while others are in this order of increase in dry matter: 2nd, 1st, 5th and 6th with percentage dry matter of (87.10%), (85.15%), (81.82%) and (81.16%), respectively.

Table 4.7: Proximate Composition of stored *Clariasgariepinus* Fried with vegetable oil

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01 □	75.82±0.01 □	48.96±0.01□	8.21±0.01□	11.61±0.1□	31.21±0.01 □
1st Week	14.85±0.01 □	85.15±0.01 □	42.58±0.01□	36.25±0.01 □	2.95±0.02□	3.34±0.02□
2nd Week	12.90±0.01 □	87.10±0.01 □	46.41±0.09□	29.95±0.04 □	6.23±0.04□	17.40±0.13 □
3rd Week	11.98±0.01 □	88.02±0.01 □	46.54±2.51□	6.70±0.06□	14.15±0.01 □	37.59±0.01 □
4th Week	31.24±0.01 □	68.02±0.01 □	21.44±0.01□	7.69±0.01□	3.28±0.01□	68.14±0.01 □
5th Week	18.18±0.02 □	81.82±0.02 □	45.00±0.02□	7.69±0.01□	8.55±0.02□	46.75±0.01 □
6th Week	18.52±0.02 □	81.48±0.02 □	33.49±0.01□	5.26±0.01□	3.51±0.01□	57.74±0.02 □
Mean	18.83±1.41	81.16±1.42	40.63±2.06	14.54±2.66	7.18±0.92	37.45±4.66

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

Percentage crude protein was higher in control, but was comparable to 2nd (46.41%) and3rd(46.54%) in which the latter was comparable to 5th (45.00%). Similarly, there was significant ($p<0.05$) difference between 1st (42.58%) and 6th (40.63%). The effect of frying on oil contents of *C.gariepinus* was significantly ($p<0.05$) higher in 1st (36.25%) followed by 2nd (29.95%). In contrast, there was no significant difference ($p>0.05$) between 4th and 5th having (7.69%) each, but differed significantly ($p<0.05$) from 3rd (6.70%) and 6th (5.26%). Frying catfish with vegetable oil increased ash contents significantly ($p<0.05$) in 3rd collection (14.15%) compared to control. There was significant ($p<0.05$) reduction in ash contents with frying in this order: 5th (8.55%) > 2nd (6.23%) > 6th (3.51%) > 4th (3.28%) >1st (2.95%). Nitrogen free extract increased significantly ($p<0.05$) in 4th (68.14%) with frying compared to control (31.21%). The remaining frying period also showed significant ($p<0.05$) difference with 6th (57.74%) second highest in energy value. This was followed by 5th (46.75%), 3rd (37.59%), 2nd (17.40%) and the least was in 1st (3.34%).

4.8 Proximate composition of stored *C. gariepinus* fried with palm oil

The effect of frying with palm oil on proximate composition of *C.gariepinus*is shown in Table 4.8. Proximate composition of *Clariasgariepinus* varied significantly ($p<0.05$) with frying periods. Moisture content was significantly ($p<0.05$) higher in 1st (32.45%) than all the processing periods and control. There was significant ($p<0.05$) reduction in moisture contents from 3rd (30.14%) period 24.17% in 6th period. Similarly, 2nd (16.93%) was significantly ($p<0.05$) higher than 4th and 6th with 10.72% each. Frying with palm oil improved dry matter in 4th and 5th period significantly ($p<0.05$) having (89.28%) each.

Table 4.8: Proximate Composition of stored *Clariasgariepinus*Fried with Palm Oil

Period	Moisture	Dry matter	% C. P.	% Lipid	% Ash	% NFE
Control	24.18±0.01	75.82±0.01	38.11±0.01	8.21±0.01	11.62±0.00	31.21±0.00
1st Week	32.45±0.01	67.55±0.01	19.83±0.01	33.85±0.02	3.00±0.02	10.87±0.01
2nd Week	16.93±0.03	83.06±0.03	56.69±0.03	9.58±0.03	6.88±0.01	26.86±0.06
3rd Week	30.14±0.01	69.86±0.01	36.69±0.01	7.27±0.01	5.97±0.01	50.07±0.01
4th Week	10.72±0.01	89.28±0.01	19.25±0.01	5.56±0.01	3.28±0.01	68.14±0.01
5th Week	10.72±0.01	89.28±0.01	42.75±0.01	7.54±0.01	3.28±0.01	46.43±0.01
6th Week	24.17±0.01	75.83±0.01	42.63±0.02	5.56±0.01	3.84±0.03	47.94±0.01
Mean	21.33±1.82	78.67±1.81	38.11±2.92	11.13±2.09	5.41±0.65	40.22±3.87

Means with the same superscript along the column are not significantly ($p>0.05$) different.

Key:

Control= fresh fish

C P = Crude Protein

NFE = Nitrogen Free Extract/carbohydrates

Dry matter decreased to (83.06%) in 2nd period, but it was significantly ($p<0.05$) higher than 6thperiod (75.83%) and the latter was higher than 3rdperiod (69.86%) and the least was in 1st (67.55%) period. Crude protein value was significantly ($P<0.05$) higher in 2nd period (56.69%) compared to control. In the same way, 5th (42.75%) period produced significant ($p<0.05$) CP over 6th, 3rd, 1st and 4th with (42.63%), (36.49%) and (19.83%) respectively. There was significant ($p<0.05$) increase in oil contents of 1st period (33.85%) followed by 2nd period (9.58%) with control (8.21%) in third. Other periods decreased in this order: 5th (7.54%) > 3rd (7.27%) > 4th (5.56%) = 6th (5.56%). Ash (11.62%) level of control was significantly ($p<0.05$) higher than the experimental period. The ash value was significantly ($p<0.05$) higher in 2nd period (6.88%) and it was followed by 3rd period (5.97%) and 6th (3.84%). There was no significant ($p>0.05$) difference between 4th and 5th periods with (3.28%) ash contents each, but differed significantly ($p<0.05$) from 1st period (3.00%) of frying. Frying with palm oil increased energy value in 4th (68.14%) and significantly ($p<0.05$) different from 3rd period (50.07%). There was significant ($p<0.05$) decrease in energy value of *C.gariepinus* in this order: 6th (47.94%) > 5th (46.43%) > control (31.21%) > 2nd (26.86%) > 1st (10.87).

4.9 The microbial quality of processed African catfish

Table 4.9shows the microbial quality of processed African catfish. There was presence of different microorganisms in the African Catfish. *Aspergillus* spp. was present in all the processing methods,Similarly*Bacillus* spp. was also present in all the experimental parameters. *Escherichia coli* was found in the fish smoked with charcoal and*Parkia*wood,frozen and fish fried with palm oil, while fish smoked with*Anacardium* wood, fried with groundnut and vegetable oils were free from microorganisms.

Geotrichum spp. was present in charcoal and frozen storage fish but it was absent in *Parkia* and*Anacardium*wood, groundnut, vegetable and palm oils. *Klebsiella* spp. was obtained in all the processing methods except *Anacardium* wood and ground nuts oil. Similarly, *Pseudomonas* spp. was found in all the experimental methods except *Anacardium* wood processed methods. *Salmonella* spp. was found in the processed methods of ground nuts, vegetable and palm oils andfrozen method.

The species of *Shewanella* was recorded in all the methods except in charcoal processed methods. There was no *Staphylococcus* spp. in *Anacardium* wood and vegetable oil processed methods but it was present in all the other methods. *Streptococcus* spp. was obtained in charcoal, *Parkia*wood and frozen method while *Anacardium* wood, groundnut,vegetable and palm oil processing methods were free of the microbe. The species of *Spiromyces* was absent in all the experimental sample except in *Parkia*wood and vegetable oil processed methods. *Proteus* spp. was only found in fish SPWand FGO. Yeast/moulds were present in all the experimental methods but absent in*Parkia*wood processed method.

Table 4.9: Microbial quality of processed*C. gariepinus* (African catfish)

	Processing sources						
Species	Charcoal	*P/b*	*A/o*	F/method	G/oil	V/oil	P/oil
Aspergillus spp.	+	+	+	+	+	+	+
Bacillus spp.	+	+	+	+	+	+	+
Escherichia. coli	+	+	-	+	-	-	+
Geotrichum spp.	+	-	-	+	-	-	-
Klebsiella spp.	+	+	-	+	-	+	+
Pseudomonas spp.	+	+	-	+	+	+	+
Salmonella spp.	-	-	-	+	+	+	+
*Shewanella*spp.	-	+	+	+	+	+	+
Staphylococcus spp.	+	+	-	+	+	-	+
Streptococcus spp.	+	+	-	+	-	-	-
Spiromyces spp.	-	+	-	-		+	-
*Proteus*spp	-	+	-	-	+	-	-
Yeast/moulds	+	-	+	+	+	+	+

Key:

+ = Present

- = Absent

F/method = Freezing method
G/ oil = Ground nuts oil
V/oil = vegetable oil
P/oil = Palm oil
P/b = Pakiabiglobosa
A/o = Anacardiumoccidentale

CHAPTER FIVE

5.0 DISCUSSION

5.1 Proximate Composition of *Clariasgariepinus*

Freezing method had the highest moisture contents, while processing using *Parkia* had the least;similarly, processing using vegetable oil had low moisture contents. The low value of moisture contents in the processed*Clarias*using *Parkia* and vegetable oil can be attributed to intensity of heat produced by the wood that led to the evaporation of moisture. On the contrary, vegetable oil and *Parkia* had excellent dry matter than all the methods employed. Similar reason as mention above can be applicable for the observed high dry matter. Crude protein in the experimental group was highest in preservation using frying with vegetable oil. This implies that vegetable oil has the ability to improve crude protein than all the other methods tested. The oil and ash value of proximate composition of processed fish was best observed in processed samples using *Parkia* wood. This can also be accounted because the ability of hard wood to produce good heat that can exclude moisture contents to the minimal level, hence the ash contents. Charcoal produced good NFE among all the processing methods employed. This may be as a result of low heat produced by charcoal, hence the high energy contents in this method. This study is in agreement with the findings of Ayeloja *et al*. (2013) who reported proximate composition of fried and smoked catfish shows that processing methods have effect on the proximate composition of processed catfish (*Clariasgariepinus*).

5.2 Proximate Composition of *Clariasgariepinus* Subjected to different smoking materials

The nutritional quality of food is very important. The nutritional importance of fresh water fish has increased substantially because of the beneficial effects obtained from its proteins, fats and oils. The results of the analysis shows that the proximate composition of catfish smoked with charcoal at different processing intervalsof time showed a highersignificant ($p<0.05$) moisture contents thatdecreased with time of processing. This high moisture contents recorded was as a result of low heat produced by the processing method (charcoal) that did not evaporate moisture from the fish sample but it decreased with at different processing intervals. The moisture contents obtained in this study is in contrast with the findings of Mathew *et al*. (2014) who recorded low moisture content of 5.28% in the fish (catfish) sample smoked using electric oven and similar to 5.43% reported by Adeyi*et al*. (2010) in *Scomberscombrus*using coconut husk as heat treatment.

Dry matter was significantly ($p<0.05$) high in processing using vegetable oil and lower in freezing method. This increase in dry matter with processing periods was due to moisture loss with time. There was significant ($p<0.05$) decrease in protein value with increase in processingperiods. This reduction in protein contents was probably due to loss of protein with increase in processing periods. Crude protein (12.81-42.58%) obtained in this study was in disagreement with the findings(18.50% - 22.87%)of Effiong and Mohammed (2008) in dry and wet season samples of three species,*Citharinuscitharus*, *Clariasanguillaris*and *Hemisynodontismembranaceus*from Lake Kainji, Nigeria. The effect of smoking with charcoal produced significant ($p<0.05$) amount of oil. The high value observed in this study may be as a result of water loss that has takenplacethus,

minimizing the oil loss. There was general increase in ash contents with the smoking period using charcoal and it was significantly ($p<0.05$) high. Dry matter was high at the same period which directly resulted in high ash. Tenyang*et al*. (2013) recorded the values of moisture (% wet weight), crude protein, ash and fat content (% dry weight) of 76.48, 64.24, 10.98 and 23.02, respectively. The percentage Nitrogen Free Extract (NFE) increased significantly ($p<0.05$) with shelf life. The highest value recorded at this period could be due to the excess glycogen stored infish muscle for future use.

The carcass composition of *Clariasgariepinus*was affected by smoking method using *Parkiabiglobosa*. There was significant ($p<0.05$) reduction in moisture contents in all the experimental processing time intervals compared to control. Moisture contents form a bulk component of living organisms. The decrease in moisture level with increasing processing time interval observed in this study occurs as a result of evaporation of water with time. On the contrary, there was increase in dry matter compared to the control. Crude protein also increasedsignificantly at different time intervals of processing in the preserved fish. High oil contents was recorded and decreased significantly ($p<0.05$) with processing period. Oil may exude with the moisture evaporation and extended heat treatment. Smoking kiln drying seems to enhance this phenomenon. The higher and the lower value of ash was also observed accordingly. The low ash value recorded in smoking kiln dryingcould be as a result of fatty nature of Catfish which melt with intense heating thus, the reduction in ash contents. Nitrogen Free Extract was low in all the processed fish samples compared to control. The NFE value decreased significantly ($p<0.05$) with increase in processing period. This may be that NFE has the tendency of evaporation with increase in handling time that also increase the protein values in most of

the fish samples. Ogbonnaya and Ibrahim (2009) observed decrease of moisture content and increase of protein from raw (19.51%) to electric-dried (67.21%), vitamin A (0.00073%), potassium (0.00048%) and phosphorus (0.00040%) contents as the most prominent changes in catfish after drying. This trend is also in agreement with the results of Tao and Linchun (2009) who reported significant increase in protein levels (P<0.05) in dried catfish, when compared with the raw fish, suggests that protein nitrogen was not lost during drying. Nitrogen Free Extract (3.34-13.97%) recorded in this study is higher than that of Agbabiaka*et al*. (2012) who reported 1.27%, 1.84% and 1.13% in samples A, B and C of catfish.

Smoking with *Anacardiumoccidentale* affected the carcass composition of catfish significantly (p<0.05). The moisture content increased significantly (p<0.05) with processing periods. This discrepancy observed in moisture contents could be as a result of variation in heat intensity and the availability of air that facilitate the burning process of wood. Since the processing was done at different time interval hence, the differences in moisture level. On the contrary, dry matter was significantly (p<0.05) high and lowcorrespondingly at week 10 and 8 of storage. This increase in dry matter recorded is probably due water loss prior to processing. This study is in agreement with the findings of Akinneye*et al*. (2012) who recorded moisture contents that ranged from 9.79 to 16.42% in catfish using smoking methods. There was significant (p<0.05) increment in crude protein level in the processed fish samples. It could be as a result of protein feed conversion ratio available to fish. This result is in agreement with the findings of Abolagba*et al*. (2015), who recorded the crude protein content of smoked *Clarias*(66.5%) to be higher than fresh *Clarias*(20.5%). The oil value of *Clarias*smoked with

Anacardiumoccidentale was significantly ($p<0.05$) highand low at week 2 and 6 storage time respectively. Higher value observed could be both as a result of fatty nature of catfish and the processing method which preserved fat contents of the sample.

Similar result was obtained by Abolagba*et al*. (2015) with fat content of the smoked *Clarias*was as high as 17% while fresh *Clarias*recorded 1.3%. All the ash contents of the experimental processing period were significantly ($p<0.05$) lower than the control except one that was significantly ($p<0.05$) high. This can be linked to the presence of high dry matter obtained in the fish sample resulted in high ash value in this study. Nitrogen free extract was generally high in all the samples of fish. High NFE value observed in the fish samples in this study could be as a result of good handling method prior to and during processing methods. Rough handling of fish sample before processing will lead to more struggle by fish and more energy is being utilized. The carbohydrate content available in catfish sample was very high. A good source of instant energy that comes to the mind is the carbohydrates. It also helps in the body development and growth.

The result of this study agreed with that of Abolagba*et al*. (2015) who reported ash content of smoked *Clarias*to be as high as 9.6% value but their control was far lower than the one observed in this study of fresh *Clarias*(1.7%). On the contrary to all the value of the Nitrogen Free Extract obtained in this study were higher than their values in which the smoked *Clarias*had 1.9% while fresh *Clarias*was 1.5%.

5.3 Proximate composition of catfish Subjected to Freezing

There were variation in catfish nutritional composition with storage time. Moisture contents of *Clariasgariepinus*increased significantly ($p<0.05$) with storage period compared to control. Freezing method increased the moisture contents of catfish; this is because the fish sample has the ability to absorb water during freezing. Joseph and Lackson (2015) reported similar high moisture composition which varied from species to species with Nile tilapia having the highest composition while three spotted bream had the lowest of all the five species. Generally, there was high moisture content of catfish stored using freezing. Freezing preservation method had the ability of preserving and possibly increases moisture contents of the fish as observed in this study. There was general decrease in dry matter compared to control. This is because long storage period led to deterioration of muscle component, hence the reduction in dry matter. Crude protein increased with storage periodin all the samples compared to control but became significantly high. Protein denatures under some conditions but freezing tends to inhibit some physiological, bacterial and microbial activities which contribute to fish spoilage (Moshood*et al*., 2012). There was increase in oil value. It was found to be significantly ($p<0.05$) higher and lower at weeks 12 and 4, respectively. Lipid (oil) and moisture are invariably proportional in fish tissue. Percentage ash contents differed significantly ($p<0.05$) between control and experimental storage periods (week 1 to 12) but was found to be high and low at week 10 and 4accordingly. Ash is a measure of the mineral content of any food including fish (Omotosho*et al.,* 2011). Carbohydrate value was generally high in all the freezing period but it decreased significantly ($p<0.05$) with time. It was found to be high at week 4 while the low value was recorded at week 10. Shearer (1994) and Morris (2001) stated that protein and ash content do not vary as often as lipid, since it

is not necessarily impacted by diet but mainly by species type, genetics characteristics and size. Fish protein is a high quality protein that is easily digestible and fish diets reduce levels of cholesterol in the blood, thereby reducing risk of heart disease (Abolagba*et al*., 2015). Satisfying the indispensable amino acids requirements of a species is of utmost importance in preparing well balanced diets. Abolagba*et al*. (2015) reported the ash content of the smoked *Clarias*had a higher value of 9.6% than fresh *Clarias*(1.7%).

5.4 Proximate Composition of Catfish Subjected to Frying

The composition of catfish differed significantly ($p<0.05$) between control and frying period with groundnut-oil. There was decrease in moisture level as the frying increased. This is because frying has the ability to evaporate moisture. Frying with groundnut oil increased dry matter significantly. The increase in dry matter could be as a result of reduction in moisture contents due to the effect of heating. The percentage crude protein decreased significantly ($p<0.05$) from control been higher than all the frying periods. There were significant ($p<0.05$) higher proteinand low protein contents. Heat is known to denature protein; frying catfish with groundnuts oil has the tendency to decrease protein level as observed in this study. The oil value of catfish was significantly ($p<0.05$) higher at week 1 and 2 having same oil contents, with the low value observed week 6. Frying has the ability to reduce the oil value with increased of storage period; thus, the lowest contents recorded at week 6. Ash level was found to be significantly ($p<0.05$) higher in control than experimental frying periods. The lowest ash contentwas obtained at week 1 and 2 but increased significantly ($p<0.05$) when fried with palm-oil.Reduction in some component through frying could have led to the low ash values recorded in this

experiment. Frying using groundnuts oil increased the nitrogen free extract of the catfish significantly ($p<0.05$). TheNFE differences observed in this study could be as a result of variation in stored glycogen in the muscle of different fish samples; it is because, the measure of nitrogen free extract of an organism is determined by the feed and the ability of organism's system to absorb it.

This resultthat showed high moisture contents in freezing methodis in accordance with Marias and Erasmus (1977) who found out that fresh fish samples have high moisture content with low fat while the smoked samples have low moisture content but high fat. High protein is desirable for a growing child and low lipid is equally desirable as to reduce oxidation and rancidity in the fish products which cause off-flavour and bad taste in fish products. According to Obaroh*et al.* (2009), the lipid content of each adult species studied is higher than its juvenile species.Shul'man (1972) also stated that the fat content of fish increases with age. Majority of the fishes (87%) contained <2% ash contents. The concentrations of minerals and trace elements that contribute to the total ash contents are known to vary in fish depending on their feeding behavior, environment, ecosystem and migration even within the same area (Andres, 2000; Canli, 2003). Ogbonnaya and Ibrahim (2009) reported an increase in carbohydrate level from 4.88% in raw to 6.24% in electric-dried samples of *Clariasgariepinus*.

The effect of frying with vegetableoil differed significantly ($p<0.05$) on proximate compositions of *C.gariepinus*. Moisture was found to be significantly ($p<0.05$) high at week 4, with least value at week 3. This discrepancy in moisture level observed in this study may be probably linked to poor storage method of the samples. It could also be as a result of high water in the tissue of sample. Dry matter in the experimental frying with

vegetable oil was higher in all the weeks than control except week 4 that had the lowest value. Higher moisture contents at week 4 can be attributed to improper evaporation of water prior to storage of the catfish samples. On the other development high dry matter recorded at week 3could be due to good nature of muscle as a result of good handling and storage method after processing. Poor handling will allow bacterial infestation and decomposition of muscles which is the bulk dry weight of catfish.

There was variation between control and the frying afterstorage period on protein compositions of catfish. Control had significantly ($p<0.05$) higher protein value compared to other processing methods. The reduction in protein contents recorded could be as a result of breakdown of amino acid that forms the building block of protein; because as heat is increased, more protein denatures. Therefore, it can account for the reduction in the protein value observed in this study. Lipid level of *C.gariepinus* fried with vegetable oil was found to be significantly ($p<0.05$) higher. High oil value noted was probably due to loss of moisture contents while frying, therefore, minimizing the melting of oil in cat fish. The ash value of catfish significantly ($p<0.05$) increased in the processed samples compared to control. The low ash contents recorded could be as a result of size and the high oil (fat) value lost while frying leaving small available dry matter that mostly contributes to ash level. There was decrease in nitrogen free extract with increase in storage time. The low carbohydrate values could be due to the fact that glycogen does not contribute much to the reserves in the fish body tissue. This study is in-line with the report of Steffens (2006), who reported that protein forms the largest quantity of dry matter in fish. This study is in contrast to the findings of Abolagba*et al*. (2015) who reported composition of *Clariasgariepinus*(Protein content 20.5%; Lipid

1.1.3%, moisture 75% and Ash 1.7%), but their result corresponded with the nutritional composition of 100 g of African Sharptooth Catfish results presented at regional fish trade in Eastern and Southern Africa-products and marketsby Caroline and Kirema (2012) with protein content of 19.64%, lipid 1.15%, moisture 76.71% and ash 1.23%.

Frying with palm oil had a significant ($p<0.05$) effect on carcass composition of *C.gariepinus*. The moisture content decreased in the fish samples with increase in processing time. The low value moisture contents recorded at these periods were as a result of evaporation due to frying effect of palm oil. Dry matter was found to be significantly ($p<0.05$) higher at weeks 4 and 5, while 1 had the least. The percentage crude protein of control recorded in this study was significantly ($p<0.05$) higher than the experimentalstorage interval for fried *C. gariepinus*. High protein contents might be linked to feeding habit of the individual fish sample in which has the ability to convert available protein in the diet. Lipid value of catfish after frying with palm oil decreased significantly ($p<0.05$) with frying time. The decrease in the protein contents of the catfish could be attributed to the ability of palm oil to denature the protein. The value of the lipid was found to be higherat week 1 and decreased at weeks 4 and 6. Decrease in oil value with increase in frying period might have caused by the oxidation of oil through heating using palm oil. Control produced significantly ($p<0.05$) higher ash contents than all the frying time. Significantly higherash value was obtained at week 2, while week 4 and had the least value. High ash contents recorded in control is due to some components of dry matter that was not burnt while processing. Frying with oil of any type is known to reduce the dry matter; hence, the ash value is affected. Nitrogen free extract was significantly ($p<0.05$) highest at week 4, while week 1 had the least value. Low values at

these periods were probably due to loss in moisture contents in which some carbohydrate components exude along.

The result of this study is in disagreement with the findings of Ali *et al*.(1996) and Dirar (1993) who studied the fermented and dried fish species of Sudan, *Labeo*sp., *Tilapia* sp. and *Clarias*sp; and reported that the chemical composition of moisture ranged between (7.1- 9%, protein 55- 65%, fat 11.3-18.2% and ash 12.5 - 22.9%.).

5.5 Microbial quality of catfish

Microbial load in the post processed fish vary from one method of processing to another. The presence of *Aspergillus* sp. and *Bacillus* sp. In fish samples subjected to all the processing methods after storage time may be attributed to the contamination of the fish samples during handling after processing. Their main habitat is humans and animals, and found mostly in the nose, throat and skin of healthy individuals (Clucas and Ward, 1996). This indicates that fresh and smoked fish with this bacteria pathogens, must have been contaminated through handling during post-harvest. In a similar study carried out by Moshood and Tengku(2012), *Bacillus aureus, Staphylococcus aureus, Proteus mirabilis, Klebsiella*sp., *Salmonella typhii*and *Streptococcus* sp. were all found to be associated with smoked fish. It was suspected that these organisms may have contaminated the smoked fish through human handlers, air and soil. The findings of MoshoodandTengku(2012) supported the findings in this study, since common bacteria such as *Staphylococcus* sp., *Salmonella* sp. and *Bacillus* sp. were also isolated. The presence of these organisms in the processed fish samples of C.*gariepinus* might be due to increase in moisture content of the product during storage, and also increase in temperature that favours the growth of these organisms.

During handling of fish, the natural flora of fish environment will be contaminated with organisms associated with man, such as *Salmonella* and *Staphylococcus,* both isolated in this investigation, can grow well at 30°C - 37°C (Brown, 2004). The findings of this study concurred with the results of Tiamiyu*et al.,* (2011) who isolated and identified *Staphylococcus aureus, Bacillus sp., Salmonella* sp. and *Streptococcus* sp. from the skin of *C. gariepinus*.It is well established that aquatic birds spread *Salmonella* sp.and other pathogen in the environment (Beveridge, 1989). *Bacillus* sp., *Salmonella* sp. and *Streptococcus* sp. have been found associated with fish-borne diseases of humans (Babu, 2000). Ikpi and Offem (2011) in a study carried out on bacterial infection of Mudfish *Clariasanguillariss* isolated and identified *Staphylococcus aureus, E.coli* and *Pseudomonas* sp. however dominating. In support of *Salmonella* sp. that was isolated in this study, *Salmonella* sp. have been recovered from gills, intestine and whole body of catfish *C. gariepinus* and sea food in Malaysia (Bremer *et. al.,* 2003; Kumar *et. al.,* 2009; Hassan *et. al.* 2010; Bundiati*et. al.,* 2011).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Preserving food and other perishable products like fish and meat generally involves processes that impede growth of micro-organisms either by addition of growth inhibiting ingredients or adjusting storage conditions by freezing or drying. It can therefore be concluded that:

Crude protein, fat, ash and moisture content of *Clariasgariepinus* differed significantly ($p<0.05$) after subjecting to various processing methods. Crude protein was highest in processing using vegetable oil and lowest in frozen method.

The shelf life of smoked, frozen and fried *Clariasgariepinus* differed with processing period.

There was presence of *Aspergillus,Bacillus, Geotrichum, Klebsiella, Pseudomonas, Salmonella*, *Shewanella*, *Staphylococcus*, *Streptococcus*, *Spiromyces*, *Proteus* species, *E. coli* and yeast/mould.

6.2 Recommendations

Based on the foregoing findings, the following are recommended:

i. Fish should be smoked with *Parkiabiglobosa*wood because it gives a better protein yield than charcoal and *Anacardiumoccidentale.*

ii. Fish should be Frozen at -30ºCfor it offers a longer shelf life than other temperature.

iii. Fish should be fried with palm as it gives a better protein content than that of vegetable oil and groundnut oil.

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APPENDICES

Appendix I: Measurement of length of fresh *Clariasgariepinus*



Appendix II: weighing of Fresh sample of *Clariasgariepinus*



Appendix III: *Clariasgariepinus* Smoked with *Parkia* wood



Appendix IV:*Clariasgariepinus* Smoked with *Anacardium* wood



Appendix v: weighing of frozen sample



Appendix VI: Weighing smoked sample



Appendix VII: Weighing fried sample



Appendix VIII: Packing processed sample

