FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

CARE FOR FISH OUT OF WATER: A VERITABLE POST HARVEST STRATEGY FOR FOOD SECURITY IN NIGERIA

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INAUGURAL LECTURE SERIES 63

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INTRODUCTION

Let us then approach God's throne of grace with confidence, so that we may receive mercy and find grace to help us in our time of need. Hebrews 4:[16]

Mr. Vice Chancellor Sir, it is by the grace of God that I am standing at this "Town and Gown meeting" to present the 63rd Inaugural lecture of this great University Federal University of Technology, Minna today. This is the sixteenth from the School of Agriculture and Agricultural Technology and fourth from the Department of Water Resources, Aquaculture and Fisheries Technology. My academic progression has been a long but sure footed one. However, according to the Psalmists in His song of Ascent *"When the Lord restored the fortunes of Zion we were like those who dreamed. Our mouths were filled with laughter, our tongues with songs of joy."* Psalms 126:[1-2]. God re-established me and filled my heart with joy today to present this Inaugural Lecture, exactly the 12th year anniversary of my PhD defence (29th March, 2006: Eclipse day) and four months and twenty seven days after being appointed Professor of Water Resources, Aquaculture and Fisheries Technology: the shortest period in the history of Inaugural presentation in the Federal University of Technology. Coincidentally, my 27 years of stewardship in the University and half my current existence on earth.

Today's lecture focuses on "henceforward" of dead fish. According to Lagler *et al.* (1977) stated what water is to fish. Its birth place, highway, byway, communication medium, nursery,

playground, school, room, bed, board, drink, toilet and grave. However, dead fish can still be beneficial and contribute the needed fish nutrient in human nutrition, if care is adequately given to it when out of water. Sadiku (2014), classified fish nutrient as the first class miracle for all stating that fish has been the richest source of nutrients especially essential nutrients – amino acids, fatty acids, vitamin and mineral and arguably unidentified growth factor (UGF), needed for body metabolism for growth, reproduction, body repairs, body activity and specific dynamic action (SDA) in all animal life, including man. Of all animal protein sources, it is the only one that can be eaten at all ages of life (infancy to old age), *ad-libitum* or to satiation without threat to life. It is widely eaten, except for obligatory vegetarians, widely used as fishmeal in feeds of poultry, livestock and aquaculture species, hence fish and fishmeal.

Fishes are diverse cold-blooded animals, typically with backbones, gills and primarily in water with over 20,500 species known to exist (Lagler *et al.,* 1977). Freshwater and sea fish constitute important sources of food for large segments of the populations of developing countries worldwide. According to Lamai (2011), fish is perhaps the most valuable item in water as far as man is concerned. It is generally observed that when there is a crowd near any water body the element of fish is the main object. However, fish is one of the most perishable foods.

Fish quality deteriorates rapidly immediately it is out of water. Just as any other dead tissue and biological materials and the potential keeping time is shortened, if they are not processed or preserved or stored properly. Substantial physical, economic and nutritional post-harvest losses occur at different points of capture, pre-processing (sorting, grading, de-scaling, gutting, washing and filleting), processing (open-air drying, oven drying, solar drying, smoking, salting, canning *etc.*), packaging, storage at low temperature (freezing, icing and refrigeration.) for fresh

fish and ambient temperature for dried fish products, transportation and marketing. These losses result from intrinsic and extrinsic factors.

These include the concentration of the substrates and metabolites in the tissues of live fish, the activity of the endogenous enzymes, the microbial contamination and the condition after catch (Sikorski *et al.*, 1990). In addition, the ambient temperature, handling on the boat, the hygiene of the processing area, equipment and the personal hygiene of the workers, the method of waste disposal, methods of packaging and storage and the mode of transportation, hasten spoilage by accelerating the activities of bacteria, enzymes and chemical oxidation of fat in fish flesh (Johnson and Clucas, 1996). Prevention of these losses will increase availability of fish protein, enhance the nutritional status of the people, and reduce fish importation, thereby conserving the Country's foreign exchange earnings.

2.0 FISH AS FOOD

Fish is regarded as an excellent source of dietary protein, fat, vitamins and minerals that are important to the human diet for the maintenance of good health. The nutritive value of protein is expressed in terms of the types of amino acids content present. Amino acids are regarded as the building blocks of protein and about 20 types of amino acids have been isolated from protein. Certain types of these amino acids are essential to the human diet for the maintenance of good health. If the basic materials (carbon and nitrogen) are provided in the diet, the body can synthesize some amino acids. These are termed non-essential or dispensable amino acids. They include alanine, proline, glycine, serine, tyrosine, asparagines, glutamic acid, aspartic acid, hydroxyproline and arginine. The remaining amino acids must be provided in the diet. These are termed essential amino acids.

They are lysine, methionine, tryptophan, isoleucine, leucine, threonine, valine, phenylalanine, arginine and histidine. The increased requirements for growth make one more amino acid, histidine essential for children (Ihekoronye and Ngoddy, 1985). Fish contains all the amino acids necessary for the development, health, repairs and the growth of human body that could not be synthesized by the body (Clucas, 1990). Also fish remains the cheapest source of good protein in the diet of a greater population of Nigerians, and its quality, in terms of the nutritional value is impressive because of its rich display of amino acids (protein/body builder). Of even greater impact is the affordability of the protein source, as it is cheaper than beef, pork and other meat sources. In developing countries including Nigeria, about 60 per cent of the protein requirement comes from fish (The Guardian, 2016).

Lipids are important dietary constituents. They contain fat-soluble vitamins A, D, E and K and essential fatty acids, which are found with the fat of natural food. The chemical composition of fish lipids differs from that of other naturally occurring fats and oils. They contain a greater proportion of highly unsaturated fatty acids, primarily of the n-3 family with chain length greater than 18 carbons (Bligh *et al.* (1988). Fish oils are rich in highly unsaturated fatty acids ($HUFA_s$) especially eicosanpentaenoic acid which, has 20 carbon atoms in the chain, 5 double bonds (20; 5) and dodecahexaenoic acid (22; 6). Both acids belong to the *n*-3 series, meaning that the first unsaturated linkage is at the third carbon atom along the carbon chain from the methyl group (Love, 1992). Alais and Linden (1999) stated that the HUFA in fish oils influence the blood lipids in two ways. They lead to a lowering of the cholesterol level accompanied by a fall in the triglycerides level, which contribute to good health. Heart attacks and strokes are usually caused by hardening of the arteries and a contributory cause of this is the formation of blood clots, which eventually clog the coronary artery (Lands, 1986). Once

obstructed, blood flow through the arteries is slowed with resultant hardening of the vessels. Cholesterol is considered to be the principal cause in forming blood clots and fish fats are beneficial in preventing arterial blockage by reducing blood cholesterol. Myocardial infarcts (portion of heart tissue dying because of cut off in blood supply to the heart) patients put on a diet of fatty fish, appear to have a greatly reduced likelihood of recurrence and arteriosclerosis (a form or stage of thickening of the inner coat of arteries) is reduced. Arteriosclerosis facilitates myocardial infarct and this may lead to cardiac arrest or failure. The issue of coronary heart disease is one of the global major concerns in human health today (Love, 1992). Also, when Eskimos and the Japanese used fish as the main part of their food intake; they almost never suffered from heart attacks. Many other diseases such as rheumatoid arthritis (inflammation and swelling of joints often leading to their complete stiffening and even cancer (any malignant new growth or tumour or disorderly growth of epithelial cells which invade an adjacent tissue and spread by lymphatic and blood vessels to other parts of the body), appear to be alleviated by incorporating fish oils into the patient's diets. The possible explanation to this predisposition is the presence of n-3 acids in seafood, which protect against the above-mentioned diseases. Fish fats also have a possible role in the body's immune system, which defends against invading bacteria **(Love, 1992)**.

Fifteen different vitamins are recognized as being necessary for man and all of them are found in fish although distributed differently. For example, in the cod family most vitamins A and D are found in the liver whereas in herring most are found in body tissues. This is because vitamins A and D are fat soluble and therefore concentrated where fat is deposited. Vitamin C is concentrated in the adrenal gland while fish roe is a good source of the vitamin B complex. This includes vitamin B1 (thiamine) and vitamin.B2 (riboflavin). Fish liver is also a rich source of

vitamin B3 (niacin and folic acid), vitamin B6 (pyridoxine), vitamin B12 (cobalamine), vitamin E (tocopherols) and vitamin K (phylloquinone).

When fish bones are eaten they also afford a rich source of Calcium and Phosphorus, which are needed for healthy teeth and bones. Finally, iron and copper are required in red blood cell formation. Sea fish is also a good source of iodine, a deficiency of which causes the disease goitre.

3.0 STATUS OF FISH PRODUCTION AND FOOD SECURITY IN NIGERIA

Nigeria's coastline runs for 840 kilometers between its international borders with Benin to the west and Cameroon to the south. The territorial sea and Exclusive Economic Zone (EEZ) extend more than 200 nautical miles into the Atlantic Ocean and cover an area approximately 256,000Km^2 (Akande and Asuquo-King, 2000). Also, Nigeria possesses vast inland water resources of about 12.5 million hectares of water bodies which are made up of natural and man-made lakes, rivers and reservoirs (Ita *et al.* 1983). Nigeria's main Rivers are Benue and Niger to mention a few. The Niger, Africa's third-longest river and the main source of Nigeria's inland water.

The Niger feeds numerous freshwater ecosystems along its length and fills 13 lakes and reservoirs covering an area of up to 853,600 hectares. With the exception of Lake Chad, all of these lakes are man-made; these include Lakes Kainji, Shiroro, Gioronnyo, Rima, Challawa (Shimang, 1990). At the Niger delta on the Nigerian coast, the freshwater river meets the saline Atlantic Ocean, creating ideal conditions for mangrove swamps. The mangrove ecosystem is estimated at between 500,000 and 885,000 hectares. It is also noteworthy that 13 out of the 36

States in Nigeria are named after Rivers. These are Anambra, Benue, Cross River, Imo, Kaduna, Kwara, Niger, Ogun, Osun, Sokoto, Yobe and Zamfara.

The total fish demand for Nigeria based on the 2014 population estimate of 180 million was 3.32 million metric tons. However, the domestic fish production from Aquaculture, Artisanal and Industrial fisheries for 2014 was 1.123 million metric tons (Figure 1). The implication is that just 30% of this demand is met domestically, resulting in an annual expenditure of N125 billion (US$625m) on fish imports (FCWC, 2016).

Though there was an increase in fish supply over the succeeding years, the growing population seemed to have paled the effort, as shown in the Federal Department of Fisheries (FDF), projected human population, fish demand and supply in 2008 to 2015 (Table 1). There may be slight differences in the overall statistics, but the fact remains that there is shortfall, and the nation continues to rely on importation, which has been a source of drain on the scarce foreign reserve. These shortfall and decline in the fish supply have been attributed to inefficient fisheries development and managementand poor post-harvest technology in terms of handling, preserving, processing, storage and distribution of harvested fish. However, Nigeria's inland waters can make Nigeria self-sufficient in fish production hence fish protein if properly harnessed and managed. This will advantageously enhance Nigeria fish food security and key into the concept of food security which has been defined severally as:

- The ability of food deficit regions or countries, or households within these countries, to meet target levels of consumption on a yearly basis.
- Access by all people at all times to enough food for an active and healthy life.

- The ability of individuals and households (especially the rural and urban poor) to meet staple food needs all year round. (Carter, 1989; Adisa, 1992; Eboh, 1995; Abudullahi, 2002; World Food Summit, 2003; Gurkarm, 2005; as cited in Eme *et al.* 2014).

It is obvious that Nigeria has not met any of above concepts of food security from the fishery sector, though fish contributes 40

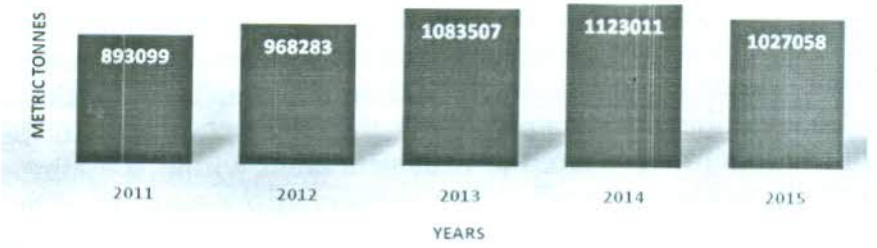

Figure 1. Fish production in Nigeria (National Bureau of Statistics 2017)

4.0 Status of fish processing technology in Nigeria

Fish processing is a fairly wide field, covering a large number of processing techniques, fish species, fish products, fish by-products and processing technologies. The basic functions of fish processing include, preservation of the product, converting the raw fish to a desirable form, maintaining product quality, assuring consumer's safety and full utilization of the raw material (Wheaton and Lawson, 1985). The traditional methods of fish preservation in Nigeria include smoking, sun drying and salting/sun drying. The use of these methods could be attributed to their simplicity, practicability and acceptability in remote villages where the technology for other preservation methods like freezing and chilling are not feasible.

4.1 Processing methods

· Smoking

As obtained in most developing countries, the main aim of

smoking in Nigeria is still regarded as a preserving rather than a processing method of fish catch. This is because about 50% of the total fish production in Nigeria is from the artisanal sector. This sector is largely made up of remote coastal and brackish water, inland rivers and lakes where electricity to power other forms of preservation methods are lacking. 60-65% of the total fish landing is from inland waters (Eyo, 1992a). The preservative effect of the smoking process is primarily due to the drying of the fish during the smoking, anti-oxidative activity of the phenol component of the smoke and the bactericidal effect of the carboxylic and phenol components of the smoke (Miler and Sikorski, 1990). Smoking in Nigeria is commonly carried out in kilns, which are either traditional or modern. The traditional smoking kilns are cheap; however they need close monitoring during operation. Also, the heat generated within the kiln is usually neither controlled nor conserved. As such, they are inefficient in their use of fuel.

Table 1: Projected Human Population, Fish Demand and Supply in Nigeria (2000-2015)

Year	Projected Population (Million)	Projected Fish Demand (Tonnes)	Projected Domestic Fish Supply (Tonnes)	Deficit (Tonnes)
2000	114.4	1,430.00	467.098	962.902
2001	117.6	1,470.00	480.163	984.836
2002	121.0	1,412.00	507.928	1,004.572
2003	124.4	1555.00	522.627	1,063.082
2004	128.0	1600.00	536.917	1,063.072
2005	131.5	1643.75	552.433	1,091.317
2006	135.3	1691.25	567.948	1,230.301
2007	139.1	1732.75	583.872	1,154.873
2008	143.0	1782.30	600.612	1,186.887
2009	147.1	1838.75	617.353	1,221.397
2010	151.2	1810.00	634.500	1,221.397
2011	155.5	1943.75	652.606	1,291.143
2012	160.0	2000.00	689.958	1,328.508
2013	164.0	2113.75	709.683	1,365.042
2014	169.1	2175.00	730.248	1,404.067
2015	174.0	2,055.00	671.492	1,444.752

Source: (FDF, 2008) (Tonnes x 1000) cited in Ozigbo *et al., 2014*

The fish products from the traditional kiln are usually of poor quality due to over cooking of flesh inside, burning and charring of the outside. Several modern smoking kilns have been designed and tested in Nigeria. These include, Altona, modified Altona or Watanabe, Chorkor and Kainji Gas Kilns. The modern kilns usually have comparative advantages over the traditional kilns. These include efficient use of fuel, ease of operation uniformity of smoked product portability, high carrying capacity and low cost of construction. Fish are usually not salted and some may be dressed and gutted before they are smoked. Smoke is usually supplied by wood or dried grass for the traditional kilns. For the modern kilns apart from firewood other sources of fuel are used. These include charcoal and domestic cooking gas.

- **Open-air drying**

Open-air drying is another traditional form of fish preservation in Nigeria. Fish to be dried are usually spread on the ground or at best on a rack. The drying is done through removal of moisture by evaporation from the fish. The dried products are usually exposed to dirt, contaminants and are susceptible to climatic conditions and animal attack. Sun or open air-drying is practiced mainly in the Sahel zone in the Northern part of the Country where sunlight is in abundance.

- **Enclosed solar drying**

This is the using of solar dryers made of plastic or glass to trap solar energy for a more efficient use which is an effort to improve on open-air drying. Temperatures in excess of 45^{0}C are attainable inside solar dryers; insects and their larvae get killed. At temperatures over 60^{0}C, the eggs of the insects are killed. Furthermore, a cleaner product is obtained in a solar dryer **(Eyo, 2000)**. At present, the use of solar dryers in fish drying in Nigeria is at subsistence and research levels.

5.0 POST-MORTEM CHANGES IN FISH

Fish is a highly perishable animal with a perilously short shelf life if it is not kept properly post-harvest, that is after it is harvested. Spoilage sets in along the chain of handling, processing, preserving storing, transporting and marketing. Under surrounding room temperature, especially in the tropical areas including Nigeria, fish spoils rapidly within 12 - 20 hours after catch depending on the species of the fish, method of capture, surrounding temperature, size and other factors.

Immediately fish dies the quality remains wholesome for only a short time. At this period, according to Johnson and Clucas (1996), the gills are dark red in colour, with some thin clear slime and a marine smell. The eyes are bright metallic with clear convex pupils. The body appearance has natural colours iridescent having firm scales with little or no slime. The texture is firm before or in rigor. The quality at this point in time is excellent and of first grade. However the period at which the fish stays in this rigor mortis condition depends largely on the post-harvest biochemical and microbial changes in the fish tissue. Sikorski *et al.* (1990) stated that these changes depend very significantly upon the factors which affect the concentration of substrates and metabolites in the tissues of live fish, the activity of the endogenous enzymes, the microbial contamination and conditions after catch, (Table 2). At death the normal defense mechanisms of fish stop working and a series of changes begin that cause spoilage. Firstly, the controlled biochemical processes that occur in all living animals to assist the digestion of food continue after death in an uncontrolled manner. The digestive enzymes attack the surrounding flesh, which is sterile. Secondly, soon after death, the microorganisms on the skin, slime and intestines multiply rapidly and spread into the softened flesh under the skin and around the belly. The spread into the flesh is more rapid if the fish has been damaged in any way. Also,

atmospheric oxygen can attack unsaturated oils in fish causing rancidity, off-odours and off-flavours. This is especially important in fatty fish species (Price, 1998; O'Grady, 2003). Thus, the general course of events leading to fish spoilage involves enzymatic actions (rigor mortis, autolysis and lipolysis), bacterial actions and fat oxidation.

5.1 Rigormortis

Sikorski *et al.* (1990) described rigor mortis as a phenomenon of catabolic processes taking place in a dead animal body leading to stiffening of the muscles. The flesh, which just after death is pliable, limp and elastic under light stress, turns stiff, hard and inextensible, causing the body of the fish in rigor often to have a bent form. The stiffness of a fish in rigor is a sure sign of freshness. After several hours, the rigid fish gradually softens and becomes pliable again. Love, (1992) stated that the time a fish takes to go into and pass through, rigor depends on the following factors: the species, physical condition, the degree of exhaustion before death, size, the amount of handling during rigor and the temperature at which the fish is kept. Also, rigor can affect the quality of whole fish in three main ways, by causing gaping in wet and frozen fish and toughness and excessive drip loss on thawing in frozen fish (Stroud, 1969).

5.2 Autolysis

As soon as a fish dies, a series of changes start to take place, which is collectively known as spoilage. The degradation of the tissue is brought about both by indigenous fish enzymes and by microorganisms, present on the surface of the skin, on the gills and in the intestines (Clucas, 1990). At death, fish stops to eat and the energy resources soon become depleted.

Table 2: Freshness ratings

Criteria				
	Marks			
Part of fish inspected	**3**	**2**	**1**	**0**
		Appearance		
Skin	Bright, iridescent pigmentation, no discoloration Aqueous, transparent, mucus	Pigmentation bright but not lustrous Slightly cloudy mucus	Pigmentation in the process of becoming discoloured and dull Milky mucus	[1]Dull pigmentation Opaque mucus
Eye	Convex (bulging) Transparent cornea Black, bright pupil	Convex and slightly sunken Slightly opalescent cornea Black, dull pupil	Flat Opalescent cornea Opaque pupil	[1]Concave in the centre Milky cornea Grey pupil
Gills	Bright colour No mucus	Less coloured Slight traces of clear mucus	Becoming discoloured Opaque mucus	[1]Yellowish Milky mucus
Organs	Kidneys and residues of other organs should be bright red, as should the blood inside the aorta	Kidneys and residues of other organs should be dull red; blood becoming discoloured	Kidneys and residues of other organs and blood should be pale red	Kidneys and residues of other organs and should be brownish in colour
		Condition		
Flesh	Firm and elastic Smooth surface	Less elastic	Slightly soft (flaccid), less elastic Waxy (velvety) and dull surface	[1]Soft (flaccid) Scales easily detached from skin, surface rather wrinkled, inclining to mealy
Peritoneum	Sticks completely to flesh	Sticks	Sticks slightly	[1]Does not stick
		Smell		
Gills, skin abdominal cavity	Seaweed	No smell of seaweed or any bad smell	Slightly sour	[1]Sour

Source: Huss 1995

However, the enzymes continue to operate but, the function, which the enzymes perform post mortem, is to break compounds into smaller units. This breakdown of tissues affects the flavour, texture and sometimes the appearance of the fish (Clucas and Sutcliffe, 1981). The most noticeable autolytic change in the early stages of spoilage is the bursting of the belly walls of ungutted fish that have been feeding heavily; the concentration of digestive enzymes in the gut is high at this time and they soon begin to digest the gut walls and the surrounding tissues as a result of which the belly bursts producing off-odour and off-flavour while the fish muscle becomes soft and flabby (Love, 1992). Proteolytic enzymes present in the gut, skin and tissue contribute significantly to autolytic changes (Table 3). These enzymes attack the fish post-mortem and produce different changes. These changes include gradual loss of the fresh appearance of the catch and development of the signs of putrefaction. These are due to decomposition of some non-protein components, which contribute to the undesirable flavour of fish. These non-protein components include amino acids such as lysine, histidine and ornithine are broken down to cadaverine and CO_2, histamine and CO_2 and putrescine and CO_2 respectively. These biogenic amines are toxic particularly histamine and are responsible for a condition known as scombrotoxism associated with the putrefaction of mackerels and tuna in the Pacific and South East Asia particularly in Japan (Eyo, 2001).

5.4. Lipid deterioration (Rancidity)

Major changes that take place in fish lipids are generally referred to as rancidity. These changes are deleterious changes resulting in the production of off-flavours, colour, and defects and downgrading of the fish product. There are two principal types of rancidity: hydrolytic (lipolysis) and oxidative.

5.4.1. Lipolysis

Lipolysis or hydrolytic rancidity is defined as the hydrolysis of

lipid such as triglycerides accomplished enzymatically through the action of lipases yielding free fatty acids and glycerol (Alais and Linden, 1999). Phospholipids hydrolysis is the main cause of rapid accumulation of free fatty acids in frozen flesh of many species of fish (Olley *et al.,* 1962). The free fatty acid (FFA) content is the most popular measure of lipolysis in fish and it correlates closely with time and temperature (Sikorski *et al.,* 1990). In a given species of fish, the rate of lipolysis has been found to depend on the time of harvest, sex and gonad maturity and processing techniques (Kolakowska, 1978; Eyo, 2001).

5.4.2. Oxidative Rancidity

Lipid oxidation in fish concerns basically fatty species. The high degree of unsaturation in form of multiple bonds in the fatty acids renders fish lipid highly susceptible to the development of oxidative rancidity. Unsaturated lipids are oxidized and broken down to aldehydes, ketones, alcohols, short chain fatty acids and hydrocarbons. These volatile carbonyl compounds are thought to be responsible for the rancid odour and flavour, mainly cis-4 heptenal in frozen-stored cod and 2,4,7 - decatrienals in oxidized mackerel oil. The oxidation products are very reactive and decrease the sensory properties and nutritional value of fish. They may also be toxic (Arai and Kinumaki, 1980). Symptoms of rancid fat toxicity observed in experimental animals are poor growth rate, cardiomyopathy, hepatomegaly steatites, haemolytic anaemia and secondary deficiencies of Vitamins E and A. The oxidation products may also be atherogenic and carcinogenic (Sikorski and Kolakowska, 1990).

Table 3: Summary of Autolytic Changes in Chilled Fish

Enzyme(s)	Substrate	Changes Encountered
glycolytic enzymes	glycogen	production of lactic acid, pH of tissue drops, loss of water-holding capacity in muscle high temperature rigor may result in gaping
autolytic enzymes, involved in nucleotide breakdown	ATP ADP AMP IMP	loss of fresh fish flavour, gradual production of bitternes with Hx (later stages)
cathepsins	proteins, peptides	softening of tissue making processing difficult or impossible
chymotrypsin, trypsin, carboxy-peptidases	proteins, peptides	autolysis of visceral cavity in pelagics (belly- bursting)
calpain	myofibrillar proteins	softening, molt-induced softening in crustaceans
collagenases	connective tissue	gaping" of fillets softening
TMAO demethylase	TMAO	formaldehyde-induced toughening of frozen gadoid fish

5.5. Microbiological changes

When fish dies, bacteria present on the surface and in the guts multiply rapidly and invade the flesh, which provides an ideal medium for growth and multiplication. The bacteria can breakdown the muscle itself and will also feed on the smaller units produced by the autolytic action (Clucas and Sutcliffe, 1981). The increase in number of bacteria, results to a heavy slime on the skin and gills and an unpleasant pungent, offensive, sour, odour which eventually causes the flesh to soften. In addition, the gut wall may burst (Figure 2). Factors that affect the rate of growth of micro-organisms on fish include the temperature at which the fish is kept, water content, pH level and nutrient composition of the fish (Johnson and Clucas, 1996). Figure 2 shows phases of major changes due to autolysis and bacterial activities.

- **Phase 1** The fish is very fresh and has a sweet, seaweedy and delicate taste. The taste can be very slightly metallic. In cod,

haddock, whiting and flounder, the sweet taste is maximized 2-3 days after catching.

- **Phase 2** There is a loss of the characteristic odour and taste. The flesh becomes neutral but has no off-flavours. The texture is still pleasant.
- **Phase 3** There is sign of spoilage and a range of volatile, unpleasant-smelling substances is produced depending on the fish species and type of spoilage (aerobic, anaerobic). One of the volatile compounds may be trimethylamine (TMA) derived from the bacterial reduction of trimethyl-amine oxide (TMAO). TMA has a very characteristic "fishy" smell. At the beginning of the phase the off-flavour may be slightly sour, fruity and slightly bitter, especially in fatty fish. During the later stages sickly sweet, cabbage-like, ammoniacal, sulphurous and rancid smells develop. The texture becomes either soft and watery or tough and dry.
- **Phase 4** The fish can be characterized as spoiled and putrid.

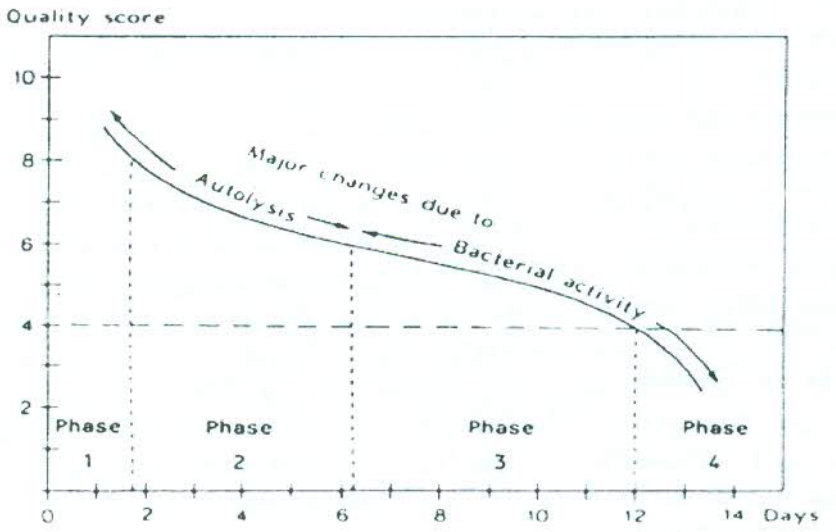

Figure 2: Major changes due to autolysis and bacterial activity on iced Cod at 0°C (Huss, 1995)

Freshly caught fish is composed predominantly of important gram-negative pathogens of warm water fish, including members of the genera *Aeromonas, Edwardsiella, Pasteurella, Pseudomonas, Vibrio, Psychrobacter, Acinetobacter, Alteromonas, Pseudomonas and Flavobacterium in* Micrococci, coryneforms and bacilli forms (Hobbs, 1987; Thune *et al.*, 1993).The end result of microbial action on fish tissue is the loss of its fresh flavour, odour and the fish becoming sour and stale (Table 4). The odour at a later stage of deterioration changes to ammoniacal (putrid and pungent), faecal and offensive. The texture of the fish is also affected.

Table 4: Typical spoilage organisms, substrate and spoilage compounds of fresh fish stored aerobically or packed in ice or at ambient temperature

Specific spoilage organism	Substrate	Typical spoilage compounds
Shewanellaputrefaciens	TMAO Cysteine Methionine Inosine, IMP	TMA, H_2S, CH_3SH, $(CH_3)_2S$, Hx
Photobacteriumphosphoreum	TMAO Inosine, IMP	TMA, Hx
Pseudomonas spp.	amino-acids (glycine, serine, leucine)	ketones, aldehydes, esters, non-H_2S sulphides
Vibrionaceae	TMAO Cysteine	TMA, H_2S
anaerobic spoilers e.g. Actinomyces, Bacteroides, Clostridium, Fusobacterium,	amino-acids, urea carbohydrates and lactate	NH_3, acetic, butyric and propionic acid

6. CONCEPT OF FISH POST HARVEST LOSSES

Generally speaking, Fish Post-Harvest Losses (PHFLs) refer to fish that is either discarded or sold at a relatively low price because of quality deterioration or owing to market dynamics. This means that fish operators (fishers, processors, traders, and other stakeholders involved in ancillary operations) lose

potential income. It also means that less fish is available to consumers, or that consumers are supplied with low-quality fish and fish products PHFL, can be physical or material, market or economic and quality or nutritional losses.

According to Diei-Ouadi and Mgawe (2011), physical fish loss refers to fish that, after capture or landing, is not used. It is either thrown away accidentally, voluntary or as authorized. Physical loss can be caused by theft, by insects eating the fish, or by bird or animal predation. Quality loss refers to fish that has undergone changes owing to spoilage or physical damage and has suffered quality deterioration. Such fish is sold for a lower price than that which would have been achieved if the fish were of "best quality". Market force loss is a loss caused by unexpected market demand and supply situations. These cause operators to sell their product at a price below expectations. The loss is the difference between the expected price and the actual price.

Several factors which tend to influence the rate of FPHL of fresh fish include:

- **Time between death and final use or consumption:** Even if fish are chilled using ice, they will gradually spoil over time; processed fish quality also deteriorates over time.

- **Temperature abuse:** High ambient temperatures, such as 20°C, create favourable conditions for fish spoilage. Low temperatures, such as 5°C and below, slow the action of bacteria and the rate of spoilage, helping to reduce losses.

- **Handling practices**: Poor handling practices lead to sustained and increased microbial contamination, hastening the spoilage rate of fish. Such practices include:

using dirty canoes, equipment, fish boxes and baskets; not washing fish; washing fish in dirty water; placing fish on dirty surfaces; and physically damaging fish by throwing or standing on them.

- Discarding of by catch at sea because fish is too small or not valuable enough to land for sale;
- Poor processing techniques damaging fish;
- Animal predation and insect infestation;
- Inadequate packaging and storage practices leading to damage of the end product;
- Market dynamics, especially fluctuations in demand and supply of fish and fish products, affect price and therefore income.
- These factors/causes along the chain of distribution can further be summarized in Table Records have shown that 20-50% of fish produced are lost after harvest at various points from capture to marketing. This colossal waste has been attributed to poor and under developed post-harvest processing and preservation practices in the country (Azeza, 1986; Eyo, 1998 Shimang, 1990 and Oyero, 2001). As such, the importance and the need for a developed fish processing and preservation industry in Nigeria, cannot be over emphasized.

Some of the benefits of a developed processing and preservation industry include availability of vital protein food supplies and employment generation for a large labour force (Akande and Asuquo-King, 2000).

Table 5: Causes of post-harvest fish losses

Stage	Causes	Loss type
During fishing	Use of destructive/harmful methods of fishing, such as dynamite, poison, resulting in harvesting fish that is already damaged or of inferior quality	Physical, quality
	Falling from the net or discarded as by catch	Physical
	Setting fishing gear for long periods, causing fish to spoil before the gear is hauled	Physical, quality
Holding fish on board	Delay returning to landing after fishing, and exposure of fish to high ambient temperatures at sea	Quality, physical
	Failure to gut (when practically feasible), wash and chill the fish on board	Quality
	Stepping on fish, causing physical damage	Quality
During unloading	Poor hygienic practices causing contamination	Quality
	Fish falling from the pan/crate/basket on to the shore	Physical
	Very long bargaining time at first point -of-sale, while fish is kept on the ground exposed to the sun at high ambient temperatures	Quality
	Theft at the landing site during offloading of fish	Physical
Fresh fish marketing	Inadequate application of ice, and no insulated container used	Quality, physical
	Limited preservation capacity during bumper catches, e.g. ice, processing equipment	Physical, quality
	No access to or lack of marketing information, with oversupply of market	Market, quality, physical
	Deliberate delay in purchasing the fish by traders	Quality
During processing and packaging	Processing of already spoiled/poor-quality fish	Quality, physical
	Processing fish under unhygienic conditions, allowing blowfly infestation	Physical, quality
	Inadequate control of heat intensity during smoking leads to over smoking of fish and possible burning	Quality, physical
	Drying fish unsupervised, on ground, rocks or herbs	Physical, quality
	Breakage or damage owing to inadequate packaging method and materials	Quality, physical
	Oxidation of fatty fish leading to rancidity	Quality
During storage	Growth of mould causes spoilage and makes the fish damp	Quality
	Insects consume fish during storage	Physical, quality
	Discoloration owing to chemical changes	Quality
	Inadequate storage facilities	Quality, physical
During distribution	Delays owing to breakdown of transport vehicles and inaccessibility of production areas	Quality, physical
	Damage to fish during transportation	Physical
During marketing	Delays in selling	Quality
	Inadequate cold-storage facilities and warehouses and lack of ice	Quality, physical
	Supplying the market at the "wrong time"	Market
	Poor purchasing power of buyers/consumers	Market

Source: Diei-Ouadi and Mgawe (2011)

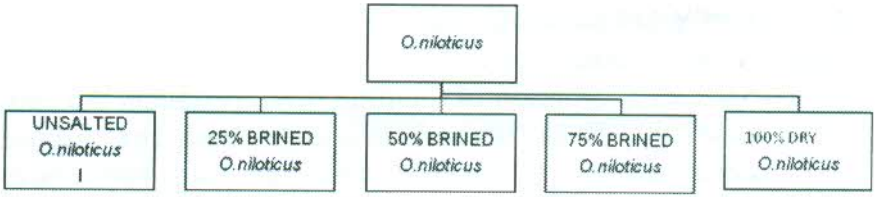

Figure 3: Salting of O. *niloticus* at different levels

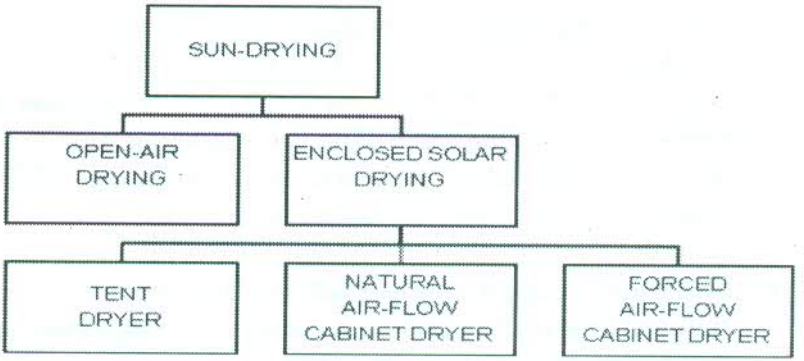

Figure 4: Experimental set-up of open-air and enclosed drying operations

In light of the various demerits associated with sun drying as a method of fish preservation, researches were carried out to improve the nutritive and keeping qualities of open-air drying through salting at different levels and improved drying with the use of enclosed solar dryers.

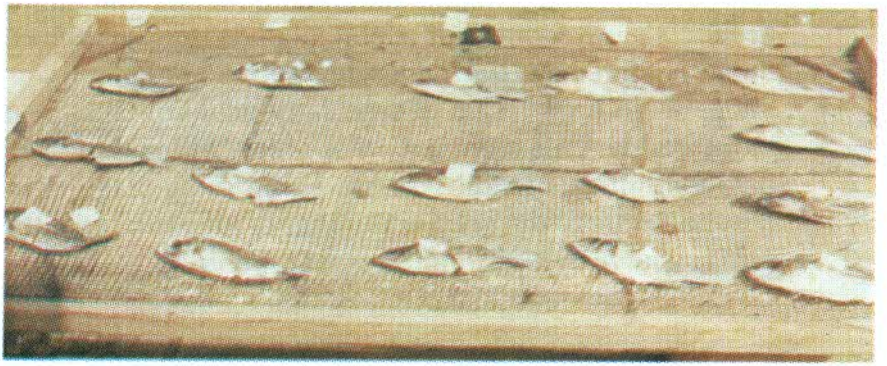

Plate 1: Open air drying of differently salted *O. niloticus*

7.1.1 OPEN AIR DRYING

Findings and Conclusions

- Sensory evaluation of the final dried products indicated that the 25% brined products had the highest acceptability while the unsalted had the lowest acceptability (Table 6).
- All the dried products showed appreciable low moisture contents that were low enough to retard the growth of spoilage organisms. The 75% brined showed the lowest moisture content of 9.44% while the unsalted showed the highest of 10.45 %(Fig 5).The various levels of moisture content in the dried products were all below 10.50% signifying limitation to bacteria spoilage and mould growth.
- The water content of fresh fish is about 80% and when reduced below 25% and 15% bacteria spoilage stops and moulds growth ceases respectively
- Reduction in the moisture content of fresh fish during drying to around 25%, bacteria cannot survive and autolytic activity greatly reduced, but to prevent mould growth, the moisture content must be reduced to 15%.
- The presence of salt retards bacterial action and, in addition, it aids the removal of water by osmosis.
- The crude protein and lipids levels of all the dried products showed an appreciable high content. However, the 25% brined had the highest level of 64.37% (Fig. 6).
- There were high levels of free fatty acid contents and iodine value. This signified an appreciable level of lipid degradation as fish oil is more liable to spoilage than other oils due to the greater number of unsaturated fatty acid as shown by high iodine number (Table 7).

Table 6: Sensory evaluation of differently salted open-air dried *O. niloticus*

SALT LEVELS	UN-SALTED	25% BRINED	50% BRINED	75% BRINED	DRY SALTED	TOTAL ± SEM
SENSORY PROPERTIES						
ACCEPTABILITY	1.93^{a}	3.33^{d}	2.33^{b}	2.33^{b}	2.53^{c}	2.51
	±0.07	±0.07	±0.07	±0.00	±0.07	±0.12
APPEARANCE	1.60^{a}	2.73^{d}	2.80^{d}	2.53^{c}	1.93^{b}	2.32
	±0.00	±0.07	±0.00	±0.07	±0.07	±0.13
COLOUR	2.60^{a}	2.73^{a}	3.53^{c}	3.60^{c}	2.93^{b}	3.08
	±0.00	±0.07	±0.07	±0.00	±0.07	±0.11
ODOUR	1.87^{a}	3.73^{d}	3.60^{cd}	3.53^{c}	2.73^{b}	3.09
	±0.07	±0.07	±0.00	±0.07	±0.07	±0.19
TASTE	1.67^{a}	3.33^{c}	2.07^{b}	1.87^{ab}	1.93^{b}	2.17
	±0.07	±0.07	±0.07	±0.07	±0.07	±0.16
TEXTURE	2.73^{a}	3.53^{bc}	3.13^{b}	3.33^{bc}	3.13^{b}	3.17
	±0.07	±0.07	±0.07	±0.07	±0.07	±0.08

Data on the same row having the same superscript were not significantly different from each other (P>0.05)

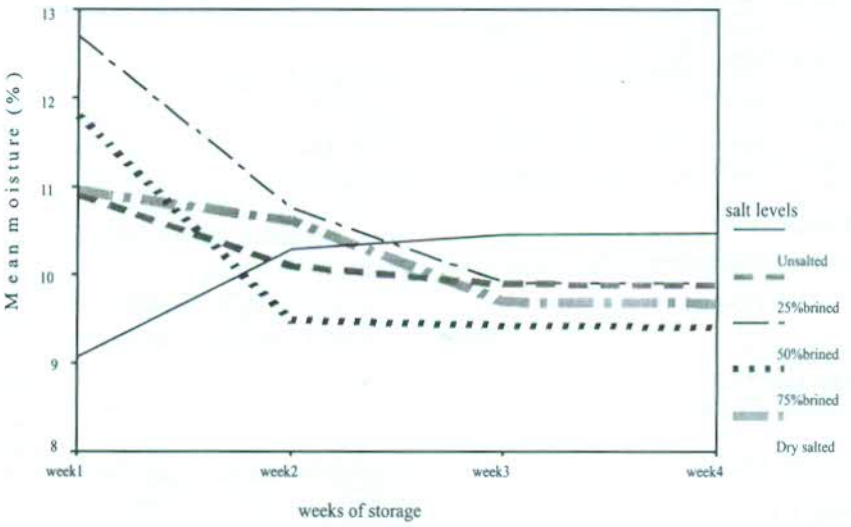

Figure 5: Weekly Evaluation of the moisture content of differently salted open-air dried *Oreochromis niloticus*

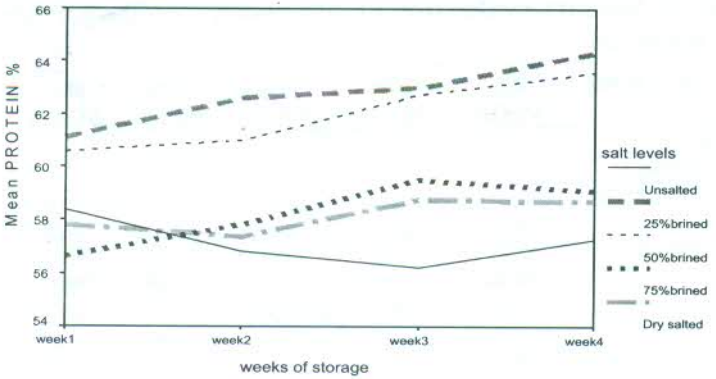

Figure 6: Percentage protein content change of differently salted open-air dried *Oreochromis niloticus*

- The degree of unsaturation is known to be highly correlated to the level of rancidity and most oils rancidity is noticeable when the free fatty acid is in the region of 0.5% - 1.5% (Eyo, 2001).
- All the dried salted products showed dark colouration indicating signs of rancidity.
- The essential amino acids (Figure 7) – arginine, lysine, valine, methionine, iso-leucine, leucine, threonine, tyrosine, tryptophan and phenylalanine showed comparable high levels to the findings of Eyo (2001).

Table 7: Free fatty acid, iodine value and total viable count - of differently salted open-air dried *O. niloticus*

SALT LEVELS	UNSALTED	25% BRINED	50% BRINED	75% BRINED	DRY SALTED	TOTAL ± SEM
STORAGE PARAMETERS						
FREE FATTY ACID	39.61^{d}	22.52^{b}	27.62^{c}	16.29^{a}	22.24^{b}	25.66
%	±0.31	±0.05	±0.28	±0.20	±0.14	±2.10
IODINE VALUE	22.78^{d}	12.83^{b}	14.63^{c}	12.24^{a}	34.41^{e}	19.38
	±0.12	±0.05	±0.17	±0.15	±0.27	±2.25
TOTAL VIABLE	8.03^{c}	3.35^{a}	40.70^{d}	3.15^{a}	6.60^{b}	12.36
COUNT x 10^{6}	±0.07	±0.03	±0.15	±0.17	±0.01	±3.82

Data on the same row having the same superscript were not significantly different from each other (P>0.05)

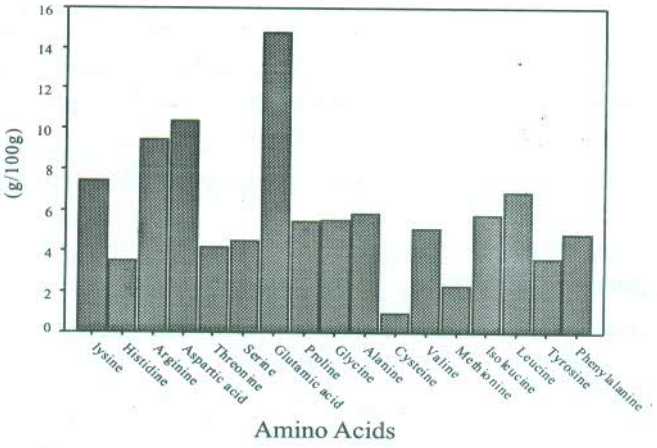

Figure 7: Amino acid composition of differently salted open-air dried *O. niloticus*

Plate 2: Solar tent dryer used in drying differently salted *o. niloticus*

Plate 3: Natural airflow cabinet dryer used in drying differently salted *O. niloticus* Designed by Z. D. Osunde, (2002).

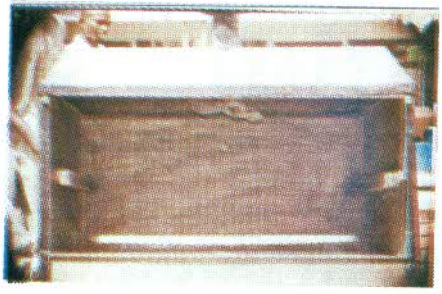

Plate 4: Forced airflow cabinet dryer used in drying differently salted *O. niloticus.* Designed by Z. D. Osunde, (2002)

- There was a direct relationship between the various parameters of appearance, colour, odour, taste and texture and acceptability of the dried *O. niloticus* products from the three drying methods of drying using tent, natural airflow cabinet and forced airflow cabinet dryers salted at different levels. None of the dried products in these two enclosed drying systems had a value less than 2.5 on the hedonic scale of measurement. This indicated that all the dried products from the two systems were widely accepted (Figure 8).
- All the enclosures had moisture content values below 10% (Figure 9). This low moisture content indicated that the dried fish products have the tendency to be very stable. Brined and dry salted products can have a shelf life up to 100 days (Trim and Curran 1983).
- There was a strong inverse relationship between the moisture and protein contents. The three unsalted dried products had the highest moisture contents. This same trend was seen for all other products (Figure 10).
- After four weeks of storage all the dried products showed protein contents well above 50% with the highest being 65.99%.
- All the dried products salted at 25% brine showed highest protein content in each of the drying methods.
- It could be concluded that to get the highest protein content using the three drying methods of STD, NACD and FACD in conjunction with salting it best to salt at 25% brine as this showed a level of consistency in the drying methods.
- All the dried products had a high level of free fatty acid indicating that all the products were becoming rancid. Eyo (2001) stated that rancidity has occurred in a fish with over 1.5% free fatty acid. Oxidation of essential fatty acids lowers their nutritional value (Figure 11).

- The amino acid profile of the dried products from the three enclosed drying systems showed that the available amino acid after drying were high when compared to the findings of Sadiku and Oladimeji (1989) on the amino acid profile of *Sarotherodon galilaeus* (Table 9).

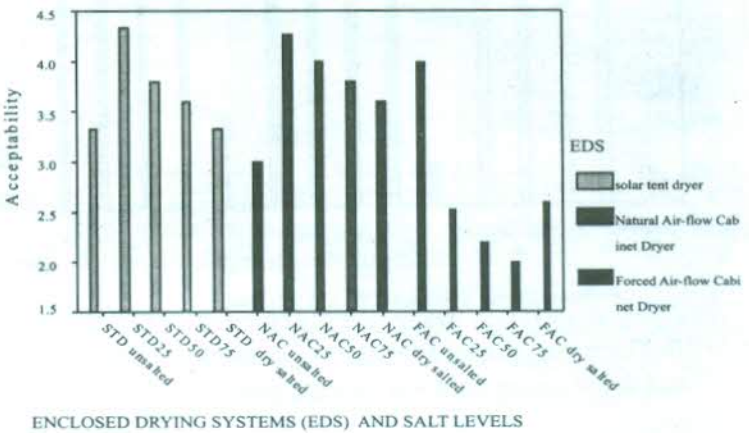

Figure 8: The mean value of acceptability of *O. niloticus* differently salted and dried using enclosed drying systems (EDS)

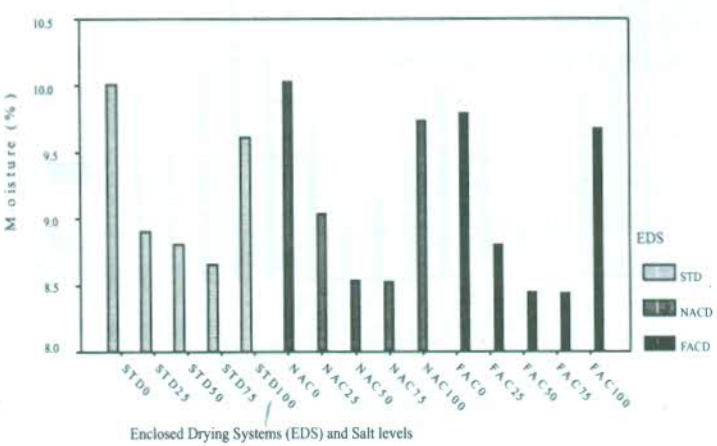

Figure 9: The mean moisture content of *O. niloticus* differently salted and dried using enclosed drying systems (EDS)

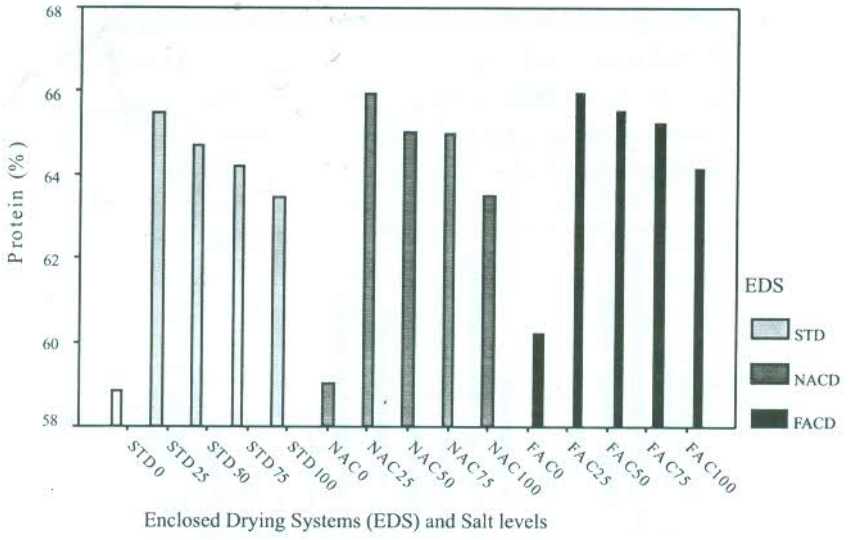

Figure 10: The mean protein content of *O. niloticus* differently salted and dried using enclosed drying systems (EDS)

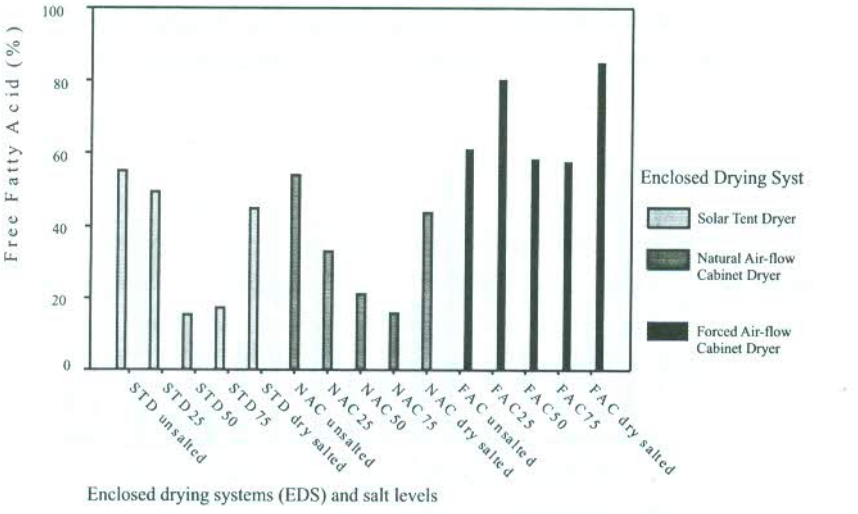

Figure 11: The percentage free fatty acid content of *O. niloticus* differently salted and dried using enclosed solar drying systems (EDS)

TABLE 8: The amino acid content of O. *niloticus* dried using enclosed solar drying systems

	AMINO ACIDS G/100g protein															
ENCLOSED DRYING SYSTEMS	Lysine	Histidine	Arginine	Aspartic acid	Threonine	Serine	Glutamic acid	Proline	Glycine	Alanine	Cystine	Valine	Methionine	Isoleucine	Leucine	Tyrosine	Phenylalanine
Solar Tent Dryer	6.93^{a} ±0.07	3.34^{a} ±0.02	9.02^{a} ±0.01	9.84 ±0.00	4.02^{a} ±0.02	4.89^{b} ±0.00	14.14^{c} ±0.01	4.94^{a} ±0.00	4.91^{a} ±0.01	5.83^{a} ±0.01	0.96^{a} ±0.00	4.83^{c} ±0.01	2.45^{c} ±0.01	5.71^{b} ±0.01	5.81^{a} ±0.01	3.21^{b} ±0.00	4.67^{a} ±0.01
Natural Airflow Cabinet Dryer	7.26^{b} ±0.01	3.64^{b} ±0.01	9.20^{b} ±0.00	9.84^{b} ±0.01	4.07^{b} ±0.01	4.69^{a} ±0.01	13.62^{a} ±0.01	5.16^{b} ±0.01	5.04^{c} ±0.01	6.26^{b} ±0.00	1.18^{b} ±0.01	4.52^{b} ±0.00	2.35^{a} ±0.00	5.78^{a} ±0.01	5.73^{b} ±0.00	3.21^{b} ±0.01	4.68^{a} ±0.01
Artificial Airflow Cabinet Dryer	7.27^{b} ±0.00	3.59^{b} ±0.03	9.19^{b} ±0.01	9.79^{a} ±0.00	4.12^{c} ±0.01	4.70^{a} ±0.01	13.85^{b} ±0.01	5.32^{c} ±0.01	5.01^{b} ±0.01	6.30^{c} ±0.01	0.97^{a} ±0.01	4.50^{a} ±0.01	2.41^{b} ±0.01	5.85^{a} ±0.01	5.73^{c} ±0.03	3.03^{a} ±0.01	4.77^{b} 0.00
±SEM	7.16 ±0.06	3.52 ±0.05	9.13 ±0.03	9.83 ±0.01	4.07 ±0.02	4.76 ±0.03	13.86 ±0.07	5.14 ±0.06	4.99 ±0.02	6.13 ±0.08	1.04 ±0.04	1.04 ±0.04	2.4 ±0.14	5.78 ±0.02	5.76 ±0.01	3.15 ±0.03	4.71 ±0.17

Data on the same row having the same superscript were not significantly from each other (P>0.05)

7.2. NUTRITIVE EVALUATION OF SMOKED FISH (Gana *et al.*, 2012; Ndakatu *et al.*, 2011a; Ndakatu *et* al., 2011b **Oyero,** 1996; **Oyero,** 1998; **Oyero** *et al.*, 2012)

In line with the efforts to improve on the existing smoking kilns, three kilns namely, traditional smoking kiln (TS), firewood fuelled improved traditional smoking kiln (FFS) and charcoal fuelled improved traditional smoking kiln (CFS) were tested to ascertain their impact on the nutritive qualities of O. niloticus.

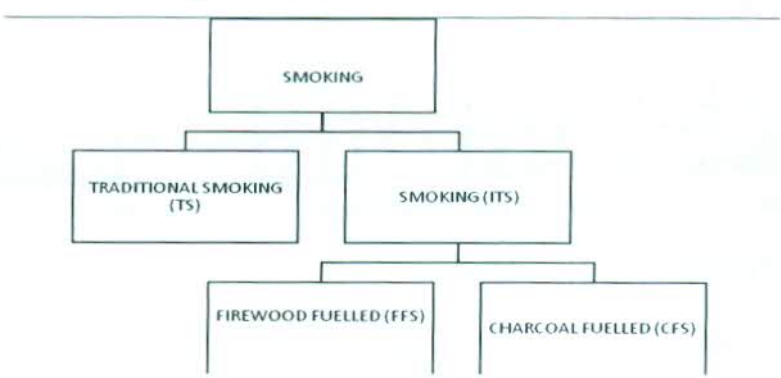

Figure 12: Set-up of the traditional and improved traditional smoking operations

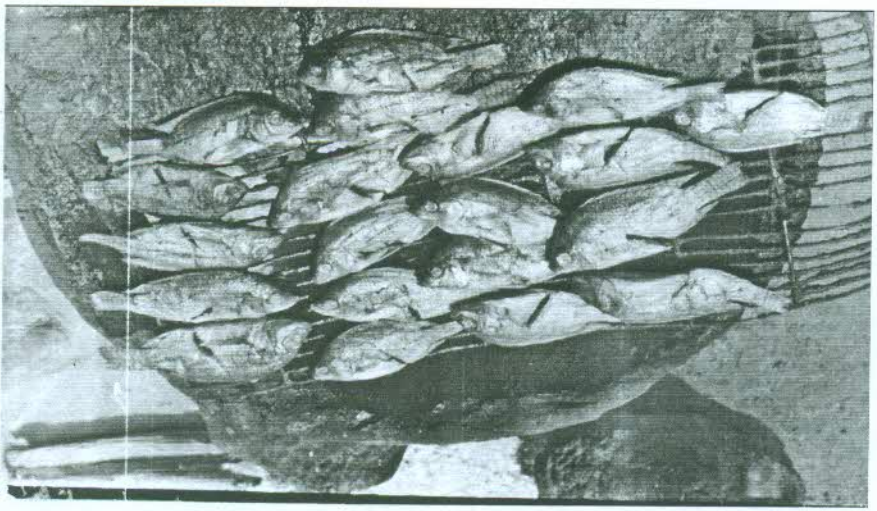

Plate 5: Traditional mud fish-smoking kiln

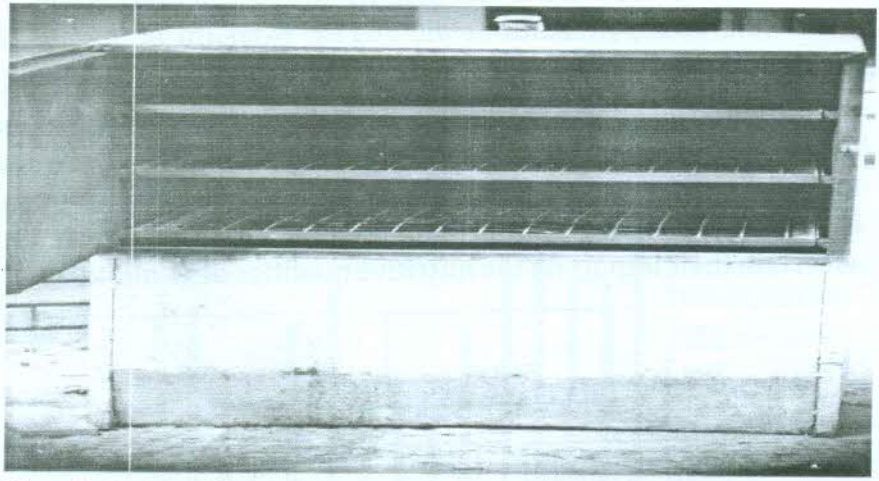

Plate 6: Firewood fuelled improved traditional smoking kiln (FFS)

Findings and Conclusions

- Despite all demerits associated with traditional form of smoking, with the application of salt at the 25% brine concentration. Moisture contents of the smoked products in all the kilns had low moisture ranging from 5.22 % for

CFS unsalted to 11.35 TS 50% brined. These levels of moisture signified that the products were well dried and indeed were stable in storage (Figure 14).

- The protein in the proximate analysis CFS 25% brined had the highest protein value of 68.49. This value might be due to the fact that there was no direct impact of the heat on the fish as the smoking chamber was separated from the fuel chamber and right combination of salt level (Figure 15).
- Smoked fish processors and marketers around Shiroro Lake should be educated about personal hygiene involved in handling of smoked fish.
- Adequate handling pre-processes of proper washing around Shiroro Lake are necessary.
- Adequate packaging is necessary for powdered fish to provide the needed nutritional quality and shelf life under ambient temperature.

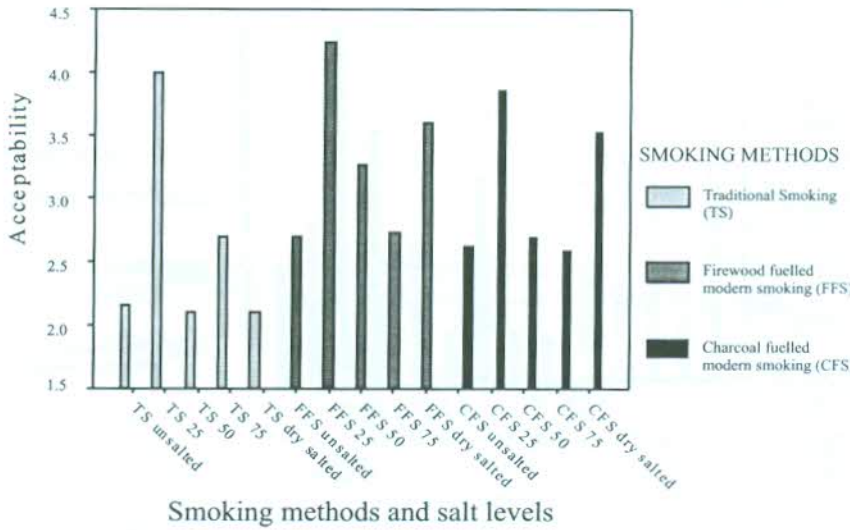

Figure 13: The mean acceptability of *O. niloticus* differently salted and smoked using smoking kilns

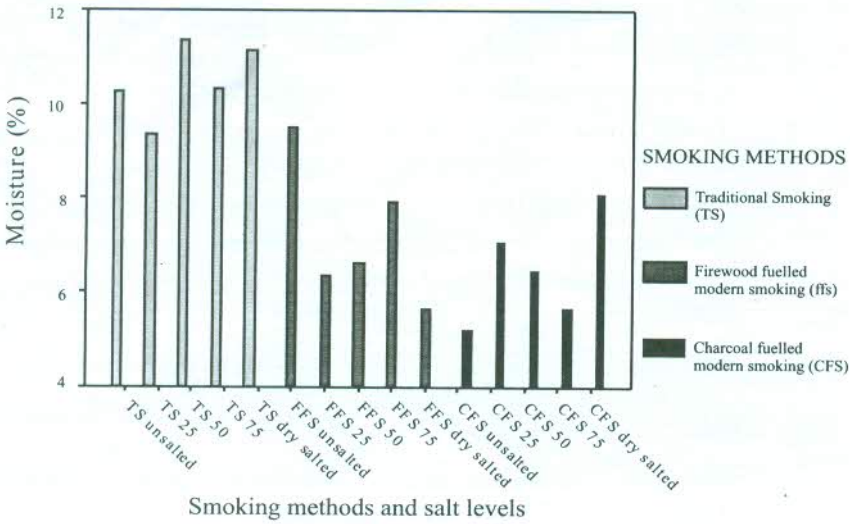

Figure 14: The mean moisture content of *O. niloticus* differently salted and smoked using smoking kilns

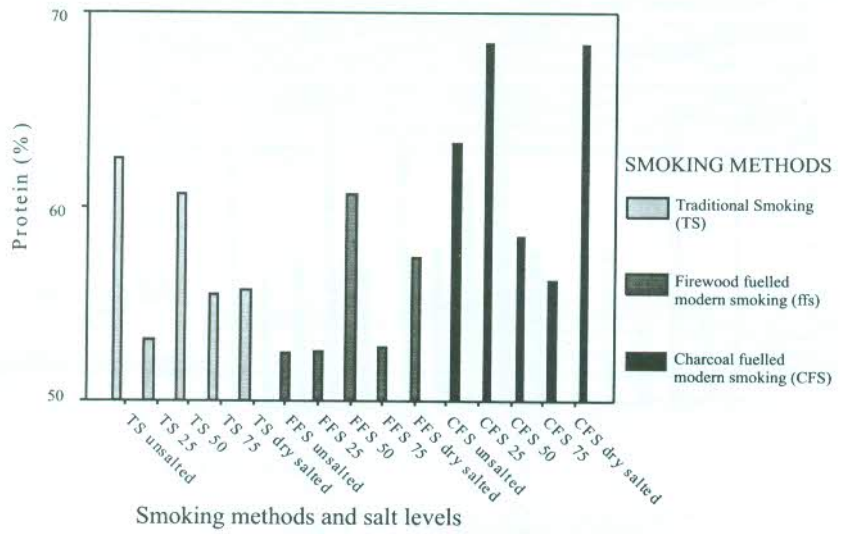

Figure 15: The mean protein content of *O. niloticus* differently salted and smoked using various smoking kilns.

7.3 MITIGATION MEASURES FOR FIREWOOD UTILIZATION (A. Ibrahim *et al.*, 2015; Ndakatu *et al.*, 2012; Umar and **Oyero**, 2018)

7.3.1 Sawdust and wood shavings

A study was conducted to determine and compare the suitability and efficiency of wood wastes (sawdust and wood shavings) as alternative energy sources to fuel wood in fish smoking with a view to enhancing optimal utilization of the wood resource.

- Sawdust and wood shavings are suitable alternatives in fish smoking because it optimizes the use of wood resource, reduces energy cost and as well promotes environmental friendly practice in waste management and comparable nutritive quality (Tables 9 and 10).

Table 9: Mean percentage organoleptic analysis of *O. niloticus* smoked with wood fuel, sawdust and wood shavings

Parameters (%)	T1	T2	T3
Appearance	3.65 ± 0.23	3.59 ± 0.23	3.29 ± 0.31
Flavour	4.12 ± 0.66	3.53 ± 0.24	3.41 ± 0.23
Taste	3.65 ± 0.24	3.59 ± 0.23	3.71 ± 0.25
Texture	3.76 ± 0.25	3.76 ± 0.16	3.65 ± 0.24
Overall acceptability	3.76 ± 0.20	3.71 ± 0.24	3.88 ± 0.28

Table 10: Mean percentage proximate composition of O. niloticus smoked with wood fuel, sawdust and wood shavings

Parameters (%)	T1	T2	T3
Moisture	7.60 ± 0.20	6.15 ± 0.07	7.27 ± 0.29
Protein	74.46 ± 3.11	72.12 ± 1.8	74.33 ± 2.84
Lipid	11.08 ± 2.10	10.68 ± 3.74	7.33 ± 0.67
Ash	7.28 ± 1.27	7.09 ± 0.22	5.77 ± 0.99

7.3.2 Melon shell briquettes

A study was conducted to determine and compare the suitability and efficiency of melon shell briquettes as an alternative energy

sources to fuel wood in fish smoking with a view to mitigate the measures in firewood utilization. Briquettes were made using a hydraulic press machine. Fish samples were smoked with fuel wood and melon shell briquettes using modified drum smoking kiln.

- Sensory (organoleptic) parameters of the samples were except their color, were not significantly different in the (taste, odor and texture) sensory attributes (Table 11).
- Proximate composition; samples were not significantly different in their crude protein, fat, moisture, ash and crude fiber contents (Table 12).
- The burning rate (BR) recorded was 0.023 and 0.022kg/min, for firewood and melon shell briquettes respectively (Table 13).
- Solid fuel from the mixing of melon shell and waste paper at 3:1 ratios was developed the densification characteristics of briquettes was 0.12,0.09 and 0.20 length, bright and mass respectively and 1.94 and 0.52 relaxation and density ratio respectively (Table 14).
- The utilization of melon shell in the production of briquettes can greatly provide alternative energy sources as bio-fuel for fish smoking, domestic cooking and also serve as a mitigation measure of deforestation.
- All the briquettes produced from these residues did not crumble during transportation and storage because of their low relaxation ratios.

Table 11: Sensory attributes of smoked *C. gariepinus* using firewood and melon shell briquettes

Parameters	Taste	Odor	Texture	Color
Firewood smoked fish	1.77±0.104	1.80±0.130	1.67±0.246	1.40±0.103
Melon shell, smoked fish	1.83±0.118	1.83±0.118	1.43±0.114	1.80±0.147

Table 12: Proximate composition of smoked *Clariasgariepinus* using firewood and melon shell briquettes

Parameters	Moisture (%)	Fat (%)	Crude Protein (%)	Ash (%)	C. F (%)	NFE (%)	TVB-N(mg)
Firewood smoked fish	14.97 ±0.55	14.76 ±0.13	45.76 ±0.41	3.15 ±0.05	1.16 ±0.04	20.28 ±0.21	30.22 ±1.81
Melon shell, smoked fish	15.84 ±0.61	13.78 ±0.18	43.51 ±0.84	3.19 ±0.05	1.14 ±0.04	22.54 ±0.53	28.82 ±0.80

Table 13: Summary of cost, smoking duration, and specific fuel consumption of firewood and melon shell briquettes used in smoking *C. gariepinus*

Parameters	Unit	Fire wood	Briquettes
Weight of fresh fish smoked	Kg	4.45	4.40
Weight of smoked fish	kg	2.15	2.55
percentage weight lost	%	51.69	42.05
Weight of fuel material used	Kg	18.2	16.8
Cost of fuel material used	?	185.71	127.83
Weight of fuel/kg of fresh fish	Kg	4.10	3.82
Cost of fuel/kg of fresh fish	?	41.73	29.10
Smoking duration	Minute	780	780
Smoking temperature	0c	48-79	40-56
Specific fuel consumption	Kg	8.47	6.59
Burning rate	Kg/min	0.023	0.022

Kg (kilogram), ₦ (Nigerian currency naira), 0_c (degree Celsius)

Table 14: Densification characteristics of melon shell briquettes produced

Parameters	Unit	Values
Physical		
Length	M	0.12
Breadth	M	0.09
Thickness	M	0.063
Mass	Kg	0.2
Number produced	Pieces	127
Combustion		
Residue moisture	%	10.9
Briquettes moisture	%	
Maximum density	Kg/m^3	0.064
Relaxed density	Kg/m^3	0.033
Compaction ratio	-	0.002
Relaxation ratio	-	1.94
Density ratio	-	0.52

7.4 Assessment of Fish Post-Harvest Losses (Oyero, J. O. *et al.*, 2013; Oyero and Oladele, 2016)

Assessment of Fish Post Harvest Losses (FPHL) in Tagwai Lake, Minna along the chain of handling, marketing and processing was carried out.

Findings and Conclusions

- The FPH losses along the chain of the landing, processing and marketing point at different locations around Tagwai Lake were very significant. The percentages of fish post-harvest processing losses in number and weight after processing were significantly higher than before processing cumulatively on the average along the chain FPH was 53.34% in weight. (Figure 16).
- Fish taken out from fishing gears were badly handled and most of the times left in the open at the canoe bottoms under ambient high temperatures. Quick spoilage especially through bacterial decomposition under the warm conditions sets in.
- Also, some of the fish having spent many hours in the net before hauling were dead in the water and have begun to spoil.
- This suggests improper preprocessing handling of washing in clean water, provision of shade for the processed fish and ignorance by the processors believing that smoking would mask the spoilage. However, smoking does not improve the quality of spoilt fish such smoked products have off odour and break easily.
- Fish displayed market sites were not gutted. Sporadically water was showered over the fresh fish to keep away flies and to make the fish moist. They were sold amidst swarms of flies and unhygienic environment.
- This leads to both quality and economic losses to the fish mongers as the market value of the fish is reduced.

- The presence of coliform bacteria such as *Bacilius subtilis Echerichia coli, Staphylococcus aureus and Klebsiella pneumonia* as revealed in the samples were pathogen associated with food poison. Also, these are majorly responsible for fish spoilage.
- The presence of *Klebisella spp* in the fresh fish samples i the fresh fish samples is an indication that the dam is feca contaminated.
- In conclusion, the presence of these bacterial isolates i indicative of public health risk.
- Lack of proper handling and distribution facilities afte harvest and unsanitary conditions during processing were the major sources of contamination identified in thi study.

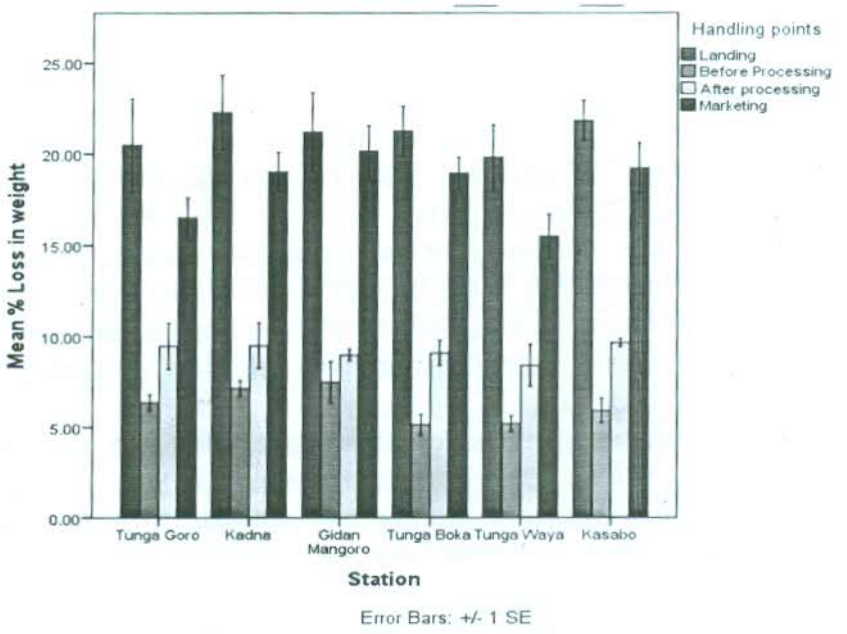

Figure 16: Mean percentage loss at various handling points around Tagwai Lake

7.5 Identification of potential hazards associated with fish in Tagwai Lake, Minna and Shiroro Lake

7.5.1. Tagwai (Oyero *et al., 2012*)

A study based on the principle of HACCP was carried out to identify potential and actual hazards associated with the harvest, distribution and utilization of fresh Tilapia species in and around Minna metropolis in order to ascertain its suitability for human consumption.

Findings and Conclusions

Tagwai Lake

- *Oreochromis niloticus* samples purchased from different sources identified associated potential physical hazards as presence of wood, cut/abrasion and dirt on the body of the samples (Table 15).
- The presence of these hazards was beyond acceptable limits and was considered a high risk and may be an access for pathogenic microorganisms.
- The Chemical hazards identified include the presence of Cu^{2+} Pb^{2+} Fe^{3+} and Mn^{2+} were beyond the tolerable limits may constitute a high risk.
- Lead (Pb^{2+}) and copper poisoning may results. This is in agreement with FAO (2004b) which stated that without proper control, it is likely to assume that unsafe levels of chemicals could be present in the fish, thus representing a significant hazard.
- The microorganisms found among the hazards identified in the fish samples were bacteria such as *Staphylococcus aureus, Shigella sonnei, Streptococcus faecalis, Pseudomonas aeruginosa, Bacillus subtilis, Shigella dysenteriae, Micrococcus luteus, Salmonella typhi, Escherichia coli, Bacillus luteus, Proteus vulgaris* with high microbial load.
- These bacteria are in excess of acceptable limits, and this

therefore constitute a significant hazard if consumed without proper and adequate processing.

- Some of the microorganisms isolated from the fish samples are of public health risk.
- For example *Staphylococcus spp, Baccillusspp, Salmonella spp, Shigellaspp and Escherichia spp* are significance in food borne diseases and they cause some of the known bacterial food borne illnesses.
- Therefore, personal sanitation by food vendors and processors and temperature at which the product is to be kept are considered critical.

Shiroro Lake (Gana *et al.*, 2014)

- Shiroro Lake was found to devoid of the presence of heavy metals Zn, Cu and Pb) capable of causing pollution which could result in environmental hazard making both the fish and water unfit for human consumption.

Table 15: List of hazards identified from the analysis of the fish samples

Location	Type of Hazard	Identified Hazard
Chanchaga market	- Physical	- Pieces of wood, cut/abrasion.
	- Chemical	- Heavy metals $Cu^{2+}Pb^{2+}$ Fe^{3+} and Mn^{2+}.
	- Microbiological	- *Staphylococcus, aureus,* - *Staphylococcus pyogenes* - *Pseudomonas aeruginosa* - *Bacillus subtilis*
Mobil market	- Physical	- Pieces of wood.
	- Chemical	- Heavy metals $Cu^{2+}Pb^{2+}$ Fe^{3+} and Mn^{2+}.
	- Microbiological	- *Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Bacillus subtilis*
Tagwai dam landing site	- Physical	- Pieces of wood, cut/abrasion
	- Chemical	- Heavy metals $Cu^{2+}Pb^{2+}$ $Fe^{3+}$and Mn^{2+}.
	- Microbiological	- *Staphylococcus aureus, Staphylococcus pyogenes, Pseudomonas aeruginosa, Bacillus subtilis*
Shiroro dam landing site	- Physical	- Pieces of wood, cut/abrasion.
	- Chemical	- Heavy metals $Cu^{2+}Pb^{2+}$ Fe^{3+} and Mn^{2+}
	- Microbiological	- *Shigelladysenteriae, Staphylococcus aureus, Pseudomonas aeruginosa*

Table 16: Comparative mean values of in *Oreochromis niloticus* from Shiroro Lake

Heavy Metals	(mg/5g) fish sample	Maximum Permissible limit WHO/FAO standard	ORGANIZATION
Zn	0.4879	19mg/day	FAO (1984)
Cu	1.0727	2000ppm	WHO (1992)
Pb	0.0577	200ppm	WHO (1992)

8.0 CONCLUSION

For any meaningful fishery development programme in Nigeria adequate consideration should be given to an improved and efficient post-harvest technology. Fish post-harvest losses exacerbate the food and nutrition insecurity and also the reliance on imports, as well as wastage of scarce resources. A reliable post-harvest intervention will contribute significantly to reducing food losses, hence alleviate food insecurity in Nigeria.

9.0 RECOMMENDATIONS

The main issue about caring for fish out of water is to reduce post-harvest fish losses in order to improve food security, secure greater post-harvest benefits and ensure sustainable livelihood for fisher folks. In achieving these, the following are recommended:

1. Government at National, State and Local levels in conjunction with Non-Governmental Organizations should invest in mass production of Enclosed Drying Systems and Charcoal fuelled improved traditional smoking kilns for the use of small scale fish processors.
2. Extension arms of various Agricultural Departments at National, State and Local levels should encourage fish processors to make use of solar dryers especially in areas of Nigeria where there is abundant solar radiation throughout the year.
3. Extension arms of various Agricultural Departments at National, State and Local levels should educate fish

processors on the advantages of drying or smoke-drying fish in conjunction with salt at 25% brine concentration.

4. Provision of support facilities: The problem of spoilage has to be tackled right from landing site until when the fish gets to the end users. To achieve this, it is necessary to provide facilities such as processing sheds at the landing sites and markets by stake holders at all levels of governance.
5. Education of fishermen and all the stake holders involved in processing and preservation of the need for proper fish handling practices. Enlightenment programmes could be arranged through cooperative societies and field extension workers of the ADPs and Federal/State Ministries of Agriculture in conjunction with the Universities and Research Institutes.
6. Product development: Apart from serving as food, fish is an important raw material for various industrial usages. Virtually every part of the fish is useful for the production of valuable industrial products. Development of these fish products and by products can greatly help in reducing post-harvest losses as well as increasing utilization of fisheries resources of Nigeria.
7. Advances in research: Efforts should be made to upscale researches in the post-harvest technology in Nigeria in terms of Hi-Tech, standardization. For example, an unbroken cold chain of refrigerated production, storage and distribution activities along with associated equipment and logistics.
8. Assessment of water bodies: There is the need to do a national assessment of losses along the post-harvest chain. This will enable Fish Post-Harvest Losses (FPHL) researchers to quantify the efforts put in curtailing FPHL have helped in reducing pressure over the dwindling fishery resources.

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"Eni ti a se loore ti ko dupe bi Olosa koni leru loni" Yoruba proverb. Meaning "An ingrate is like a thief who has robbed one of his or her possessions".

"By perseverance the snail reached the ark". by Charles Spurgeon.

"Success is no accident. It is hard work, perseverance, learning, studying, sacrifice and most of all, love of what you are doing or learning to do." - by Pele

Being here today is indeed by God's grace, sheer perseverance, supports, encouragements and prayers. The least I can do is to return thanks.

THE ALMIGHTY GOD

Praise the Lord, my soul; all my inmost being, praise his holy name. Praise the Lord, my soul, and forget not all his benefits. All praise and thanks to God Almighty, I am that I am, Alpha and Omega, The beginning and the end, The One who has restored to me the joy of His salvation and granted me a willing spirit, to sustain me, I say thank you. For giving me wisdom, knowledge, perseverance and life to get to the pinnacle of my profession despite all the obstacles and delays along the way.

Praise, my soul, the King of Heaven;
To His feet thy tribute bring.
Ransomed, healed, restored, forgiven,
Evermore His praises sing:
Praise Him, praise Him, alleluia!
Praise the everlasting King.

- Henry F. Lyte, 1834

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Vice Chancellors and Principal Officers of the University

The initial prompting of delivering this inaugural lecture was by the immediate past Vice Chancellor Professor M. A. Akanji. Thank you so much Sir for the encouragement and for making me "Akanji" Professor. I got my "stool" as an Associate Professor under you and finally got my Professorial Chair while you were still in the office. For Professor M. S. Audu the fifth substantive Vice Chancellor you are simply a gentleman and a Vice Chancellor. It still amazes me how you were able to combine intelligence with simplicity in your administration. You were simple and down to earth in all achievements which speak for you in this University. I am ceaselessly grateful to Professor

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PROFESSOR AKIM OSARHIEMEN OSUNDE

Mr. Vice Chancellor Sir, next to God in my academic carrier pursuits and progression is Brother Akim. As I always say anywhere I have opportunity to state that in my autobiography

he would surely have at least a chapter. Let me give you the glimpse of the prologue of his chapter. Here is a brother, friend, confidant and benefactor. Who spares nothing to mentor and pull his mentee up the academic ladder. He is an administrator and teacher par excellence. Meticulous in doing things and whose penchant for honesty, integrity, excellence dressing good and trust in God has no bounds. In relevance to this day in particular amongst his other benevolence to me, I want to put it on record that when Postgraduate School could not find the approval of the sponsorship of my PhD studentship by the University and was asked to pay two hundred and eleven thousand Naira **then!!!!**. I wanted to contest it, but he advised me against doing so but bailed me out with fifty thousand Naira **then!!!!**. The rest I spread over my salaries for ten months. I wonder if the defence of the PhD would not have dragged more than necessary if I did not hearken to his advice. This chapter will actually be incomplete without acknowledging my sweet aunty Engr. (Professor) Z. D. Osunde, grandma that God Has endowed with beauty and brains whose academic forthrightness is challenging. Thank you aunty for always opening your home to me as a family member.

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TOWN RELATIONSHIP

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Dr. Tunde Akinremi (Wing Commander rtd)

My president thank you for being the very first person that settled me down in Minna. Not only that you made the first set of furniture for me, you also, gave me the first opportunity to touch and operate computer in 1991. The word processing package then was WordStar. The skill acquired then has been very useful till date. I handled the word processing of my PhD thesis myself and the typing of this lecture. Thank God for knowing a God fearing gospel living person like you. You made Christianity attractive through your humility, simplicity, generosity and zealousness for the work of God. You are a testimony of God's faithfulness.

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Biola Jaiyeoba, Debo Awonaike, Femi Babalola, Demola Ojo, Remi Raji ,Tokunbo Agunloye, Yemi Cash Onavele and Kunle Alege. I acknowledge these friends of mine who were not my secondary school mates but met along my education pursuits and carrier within a period that has spanned over four decades. Together we dreamt of a bright future, success and relevance in the society. Today is a collective reality of our dreams. Thank you for ever being there for me, in terms of support, encouragement, true friendship and love.

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My Spiritual Fathers
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Prayer Partners

Cathedral Church of St. Peter, (Anglican Communion)
My Vicar I remember vividly that you prayed over my papers before being sent out hence today is a testimony of an answered prayer. Thanks for you visit to me with your wife Mummy Gladys while on sabbatical in Federal University, Wukari, it was heartening and encouraging. To other Clergy in the Cathedral: Rev. Cannon Dr. Solomon Olayimika, Rev. Cannon D. A. Yisa, their wives and all members of the Cathedral, I say thank you for your prayers and God bless.

The Sowers Society
My society in church under the Presidential leadership of Engr. Gbenga Osikomaiya, my indefatigable, resourceful brother. I appreciate the love and camaraderie that exist in the group which all of you have shown towards me since I became a member; your concern and fervent prayers at all times are also acknowledged. God bless you.

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Minna 2:7 Series and Insiders Group
Today is an evident of our prayers and study of the word of God together Thank God for using our families together for answered

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Other Prayer Partners

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In love I hereby express my thanks to my Princess, precious than ruby, the real African queen, ebony black, dream but divine made real wife for your prayers, love, understanding, perseverance and push. Pardon me for times I was to be with you but with the books or behind computers and littering your home with books. Thanks for always making sure that my study is arranged every weekend. Today is for us and your question "When are you going to be a Professor?" was answered on November 2nd 2017. Thank you so much, I love you more. Countless kisses for you.

My Vice Chancellor Sir, distinguished ladies and gentlemen of the Town and Gown I sincerely thank you for attending and patiently listening. **TO GOD BE ALL GLORY AND HONOUR AMEN.**

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PROFILE OF PROFESSOR OYERO, JOHNSON OLUSEGUN

Professor Oyero, Johnson Olusegun can aptly be described as a thoroughbred academic who has contributed immensely to the growth of his profession based on the plethora of researches he has conducted and for nurturing students through the rudiments of Water Resources, Aquaculture and Fisheries at different levels.

Prof. Oyero was born on September 26th, 1963 to Elder Gabriel Isola and Deaconess Winifred Olatunde in the ancient city of Ibadan but hails from Abeokuta, Ogun State.

He had his primary education at the Ebenezer African Church Primary School, Oke Ado, Ibadan from 1969-1973. He rounded off his secondary education at the famous Ibadan Grammar School, Ibadan, in 1978. He was also at the School of Basic Studies Polytechnic, Ibadan for his GCE/A-Level before proceeding to the premier University of Ibadan where he earned his first degree and Masters Degree in Fisheries Management in 1986 and 1988 respectively. His passion for further studies took him to the Federal University of Technology, Minna where he bagged his Ph.D degree (Fish Post- Harvest Technology) in 2006.

Having distinguished himself in his educational pursuit, Prof. Oyero started his academic carrier in the Federal University of Technology, Minna in 1991 as an Assistant Lecturer in the Department of Water Resources, Aquaculture and Fisheries Technology, School of Agriculture and Agricultural Technology (SAAT). Through sheer scholarship and dint of hard work, he

rose through the ranks to become a professor of Fisheries and Aquaculture in 2016.

His dedication to duty and painstaking research over the past 27 years has culminated in his significant contributions in the areas of fisheries management, fish post-harvest loss technology and fish utilization cum marketing. Prof. Oyero's well-documented contributions in these areas of research are outstanding and have immensely helped in simplifying the understanding of some rather complex phenomena and courses in his field of studies.

He has held several positions of responsibilities in the University such as; members, University Governing Council 2009 -2013, Ceremonies Committee, FUT, Minna Sports Committee and later Chairman between 2007-2012. He is the immediate past Chairman, Campus Radio Management Board. In the area of community services, the academic czar has deployed his expertise in advancing the fortunes of the University host communities, his home town and the country at large.

He is one of the most sought after scholars in his field based on his antecedents as a consummate researcher of repute. He is a visiting lecturer to the Federal University, Wukari, Taraba State. He is an external examiner to several Universities in Nigeria, also, a consultant to many international organisations and State governments in Nigeria. He has supervised several students at both undergraduate and postgraduate levels.

The erudite scholar has attended several conferences, seminars, workshops and other educational gathering of intellectuals within and outside the country. He is well published and cited in reputable high impact journals. The don is a member, Fisheries Society of Nigeria, World Aquaculture Society, Association of Nigerian Fisheries Scientist. Above all, Prof. Oyero is happily married to Stella Adebimpe Adesola Oyero.

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