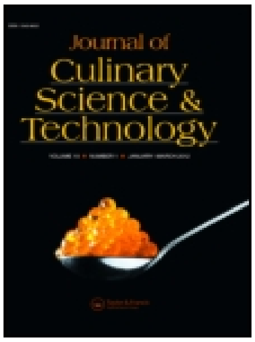

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An Overview of Traditional Fish Smoking In Africa

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ABSTRACT

This study was carried out to have a critical overview of traditional fish smoking in Africa. Fish is highly susceptible to deterioration without any preservative or processing measure, and due to its chemical composition, fish is a perishable food material, and its flavor and texture change rapidly during storage after death. Fish harvesting, handling, processing, and distribution provide livelihood for millions of people, as well as providing foreign exchange to many African countries. In many rural fishing communities, the infrastructures for post-harvest processing and preservation of fish are inadequate. As a result, losses reach up to 40% of the total catch by weight. The fishing industry, despite its importance, suffers from enormous post-harvest losses which are estimated at 35–40% of landed weight, and it is estimated that post-harvest losses remain about 25% of the total world catch annually. These losses have a profound adverse impact on fishing communities whose status and income often depend on post-harvest activities. Such losses also have a detrimental impact on the socio-economic life of the fishing communities and reduce the amount of animal protein available to a large segment of the population. In Africa, some 5% of the population, about 35 million people, depend wholly or partly on the fisheries sector, mostly artisanal fisheries, for their livelihood. Various traditional methods are employed to preserve and process fish for consumption and storage. These include smoking, drying, salting, frying, and fermenting and various combinations of these. In most countries in Africa, Nigeria, Ghana, Cote d'Ivoire, Togo, Benin, Senegal, Sierra Leone, Liberia, Kenya, Uganda, Tanzania, etc., smoking is the most widely practiced method: Practically all species of fish caught can be smoked, and it has been estimated that 70–80% of the domestic marine and freshwater catch is consumed in smoked form. However, different smoking methods are used in processing and preservation of fish by artisanal fishermen in Africa.

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Introduction

Artisanal fishing in Africa, historically dominated by fishermen in canoes and boats, has provided fish as a nutritious source of food of high quality protein often cheaper than meat. Fish consumption is not forbidden within

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religious groups, unlike eating beef, dog, and pork, which is forbidden in some religions (Agbelege & Ipinjolu, 2001).

Fish is an important source of food and income to many people in the developing world. In Africa, some 5% of the population, about 35 million people, depend wholly or partly on the fisheries sector, mostly artisanal fisheries, for their livelihood. In Nigeria, fish production through aquaculture has risen steadily from a few hundred kilograms in the 1950s to over 45,000 metric tons in 2004 (FAO, 2007). Today, aquaculture is the fastest growing livestock production sector in Nigeria, with a growth of about 29% in 2006 alone, and with prospects of continued growth. This is because demand for fish is on the increase line with population growth, while catches from fisheries are on the decline, even globally (Delagado et al., 2003). Only about 50% of the demand for fish is currently being met by local supply (Olayemi et al., 2011). The fishery sector is estimated to contribute 3.5% of Nigeria's Gross Domestic Product (GDP) and provides direct and indirect employment to over six million people (FDF, 2007). In Nigeria, the artisanal fishery occupies a significant position in the economy, contributing 4% to the total GDP, providing employment for about 5.8% of the Nigerian population, and supplying 81.9% of the total domestic fish production (FDF, 2007).

Fish can be consumed in several forms: fresh, dried, frozen, fermented, or brined, depending on consumer preference. Various traditional methods are employed to preserve and process fish for consumption and storage. These include smoking, drying, salting, frying, and fermenting and various combinations of these. In most countries in Africa—Nigeria, Ghana, Ivory Coast, Togo, Benin, Senegal, Sierra Leone, Liberia, Kenya, Uganda, Tanzania, etc.—smoking is the most widely practiced method: Practically all species of fish available in the country can be smoked, and it has been estimated that 70–80% of the domestic marine and freshwater catch is consumed in smoked form. The advantages of smoking fish are manifold. Fish smoking prolongs shelf life, enhances flavor, and increases utilization in soups and sauces. It reduces waste at times of bumper catches and permits storage for the lean season. It increases protein availability to people throughout the year and makes fish easier to pack, transport, and market. Fish smoking in most countries in Africa—Nigeria, Ghana, Cote d'Ivoire, Togo, Benin, Sierra Leone, Liberia, Kenya, Uganda, Tanzania, etc. —is traditionally carried out by women in coastal towns and villages, along river banks, and on the shores. In most fishing communities, in fact, the main economic activity of women is fish processing. Depending on the type of fish to be smoked, its uses, and possible storage period, the smoking process can take the form of "wet" hot smoking or "dry" hot smoking. Both processes are carried out at temperatures above 80°C, which are high enough to cook the fish (ECA, 1984).

As a result fish has been consumed by large proportion of the population and has become a diet staple. With the rising cost of meat and cheese protein foods, consumers have become increasingly interested in fish as a source of dietary protein. In many countries of Africa, the average diet contains less protein. Fish is the cheapest source of animal protein (Jamin & Ayinla, 2003). With the increase in human population in Nigeria, less fish will be available per capita annually (Eyo, 1997).

Since fish and fish products are perishable without any preservative and processing measures, it is imperative and essential to process and preserve fish in order to assure quality of product, health safety of the consumers, and reduce water to the barest minimum as much as possible in order to preserve the smoked fish.

The objective of this study was to have a critical overview of traditional fish smoking in Africa with a view to determine the quality and safety of traditional smoked fish in Africa.

The needs for fish smoking in Africa

Fish is highly susceptible to deterioration without any preservative or processing measures (Okonta & Ekelemu, 2005) and requires proper handling and preservation to increase its shelf life, quality, and nutritional value (Ye, 1999).

The fishing industry, despite its importance, suffers from enormous post-harvest losses, which are estimated at 35–40% of landed weight (FAO, 1981). FAO (1994) estimated that post harvest losses remain about 25% of the total world catch annually. These losses have a profound adverse impact on fishing communities whose status and income often depend on post-harvest activities. Such losses also have a detrimental impact on the socio-economic life of the fishing communities and reduce the amount of animal protein available to large segment of the population.

Methods of fish preservation in Africa

Traditional fish preservation methods have been practiced for centuries (Okomoda & Alamu, 2003). Neiland (1991) reported that traditional fish processing methods including smoking, char burning, and sun-drying, and post-harvest losses persist in Lake Chad. Kraseman (1963) has reported that people from all cultures in the world over have relied on the smoke curing of fish and meat production for long-term storage. Bonell (1994) recommended that to reduce bacterial processes immediately on dead fish, it should be beheaded, gutted, washed, and chilled to inhibit unfavorable enzymatic and microbial processes. The fish were smoked on different types of traditional ovens, round mud and kilns of different types or cut drum ovens with low batch capacities and long drying times. Akinola, Akinyemi, and Bolaji (2006) reported different types of preservation methods, such as drying, smoking, freezing, chilling, and brining. Although Akinola et al. (2006) reported that despite the rudimentary nature of process of traditional methods, lack of control of over-drying rate sometimes results in over-drying or under-drying, exposure of the fish to dust, dirt, insects infestation and contaminant such as flies, yet this method still remains predominant in Nigeria. Smoking is one of oldest and most common methods used for fish preservation in the Chad basin (Ahmed & Agbelege, 2007). Processing methods generally in practice in Nigeria are traditional and consist of sun drying, salting and sun drying, and smoke drying (Tobor, 1984). Fish were place in open pits containing smoldering wood. Although traditional ovens and kilns produce fish of uneven quality and often pose work-related health risk due to lack of control over temperature and smoke density (Adelowo et al., 1997; Clucas, 1982) mud ovens were most commonly used probably because they are cheap to build and all materials used in their construction came from local sources. Despite the health risk of smoke and the dull and unattractive color of smoked fish (Eyo, 1985), Kraseman (1963) reported that wood smoke produces microscopic particles which rise as fogs or vapor and these vapors contain volatile oils which are released from the wood and furnish the characteristics textures, flavors, and preservative qualities. Also Okoko (1996) reported that smoke drying is employed by remote fishing communities due to traditional preference of the local people for smoke-dried fish and lack of sophisticated preservation techniques. Lydia (1997) reported smoking deposits a coating of antimicrobial material or substance on the surface of the fish, while at the same time impacting an attractive sheen and pleasant taste which is cherished by the local populace. Brownell (1983) reported that, generally, smoking of fish was very common in Africa. The use of freezers to preserve fish was not very common and was employed mostly by literate fish processors. This could perhaps be a way to avoid the health and fire risk involved in smoking, as well as to avoid air pollution from charring of fish or because of their ability to purchase a freezer. Freezing methods of preservation of fish employed techniques based on temperature as is obtained in the refrigeration and freezing. Stirling (1985) reported that this preservation prevents the growth of bacteria, fungi, and micro-organisms, as well as retarding fat oxidation, which causes rancidity. Jamin and Ayinla (2003) reported that spoilage of fish is slowed down at freezing temperatures, while Adams and Moss (1985) reported that the rate of most chemical reaction are temperature dependent, and so as the temperature is lowered, the rate of chemical reaction decreases. He suggested that if not sold fresh, preservative methods such as freezing should be applied to extend the shelf life to the fish and full health safety of the fish products.

Preservation is carried out for the purpose of extending the selflife of fish (Ita, 1999; Abowei & Tawari, 2011). The major fish preservation methods in Africa are as follows:

Chilling

Chilling may be defined as cooling of fish to low temperatures without necessarily hardening fish. Chilling does not prevent spoilage. However, the colder the fish, the better and the lower are the incidences of microbial or enzymatic spoilage. Bacteria or enzyme action are not completely stopped, but they may be temporarily halted by chilling. To chill fish, the fish has to be surrounded by colder medium, which could be solid such as ice or liquids such as refrigerated water (Ita, 1999; Abowei & Tawari, 2011).

Freezing

Freezing is distinct from chilling of fish. Freezing can keep products in near perfect condition for very prolonged periods. Freezing is essential for export purposes. Freezing becomes extremely effective if it is combined with cold storage (Anthonio, 1970; Abowei & Tawari, 2011). Fish that have to be preserved by freezing should be cleaned and packed before rigor mortis sets in for easy operation and maximum use of freezing space. Fresh fish have a characteristic sweet flavor, which is due in part to inosinic acid. The breakdown of inosinic acid during autolytic spoilage resulting in the production of hypoxanthine results in the loss of the sweet flavor to bitter flavor. Sugar is produced by enzymatic action, which in turn reacts with the amino acids to produce the brownish or yellowish color found in frozen fish (Azeza, 1976; Abowei & Tawari, 2011). Pure water freezes at 0°C. Fish contains about 80% water, salts, and minerals. As would be expected therefore, fish can be frozen at temperatures lower than 0°C. As the water freezes out, the concentration of salts and chemicals increases, thereby lowering the freezing temperature. At about −5°C, up to 20% of water in fish is still unfrozen (Abowei & Tawari, 2011).

The freezing stage in fish has been divided into three. The first stage includes the period when the temperature falls rapidly to about −1°C. At −1°C, the temperature remains fairly constant and up to 75% of the water freezes. This is the thermal arrest stage, in 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; Abowei & Tawari, 2011).

These stages in the freezing of fish should be the guided in the operations of freezing fish, particularly the thermal arrest stage. If this stage is prolonged, some mechanical damage to fish tissue will occur. For example, slow freezing will produce large ice crystals in the cells, which rupture the cell walls. The salts and minerals become concentrated as the water freezes. The phenomenon also applies to enzymes, which can introduce autolysis. Some bacteria remain active at about 0°C, causing spoilage. When slowly frozen fish are allowed to thaw, spoilage can be excessive (Clucas, 1982; Abowei & Tawari, 2011).

In the process of freezing, heat is transferred from the fish to be frozen to some of the surrounding adjacent material. It is necessary that a sufficiently cold surrounding must be supplied to effect this change (Davies, 1997). The cold temperature is supplied by a refrigeration plant. Most refrigeration plants operate by the following method:

- A gas is piped into a compressor, which causes the temperature to rise at higher pressure.
- The compressed gas is released into a cooled condenser, where at the high pressure, the gas condenses into gas liquid. The latent heat of the compressed gas is transferred to the coolant.
- The liquid gas is passed to evaporator, where at the lower pressure, the liquefied gas boils and evaporates into a gas. Heat is drawn from the surrounding, which cools down.
- The gas is directed back to the compressor and the cycle is repeated.

It is obvious that fish in the vicinity of the evaporator loses heat as the liquid boils and evaporates. The refrigerant is kept in a closed circuit of pipes and heat is drawn from the fish through the pipes in the evaporator section of the plant (Davies, 1997).

Drying

Drying is defined as the removal of water by evaporation. When applied to fish, drying is the removal of water by any method as a means of fish preservation to prolong the shelf life. In areas where sun drying is used traditionally, the effects of wind and weather conditions are important. Basically, the drying effect of the sun depends on the emission of heat from the sun. This is transferred to the fish, and it is accompanied by heat transfer within the fish. During drying, the fish shrinks and undergoes irreversible changes. Water is removed from the surface in the following sequence. Firstly, water on the surface of fish evaporates. Water migrates to the surface of the fish from within fish tissues and evaporates. The air surrounding the fish then experiences a drop in temperature. This is accompanied by cooling of the surface of the fish. The energy required to drive the moisture from the surface of the fish can be obtained from a variety of sources, including wood smoke, sun drying, solar drier electricity, and mechanical driers (Davies, 1997; Abowei & Tawari, 2011).

During drying, water is removed from the surface of the fish. As the surface water is removed, it is replaced by water drawn up from the fish tissue, which leaves the fish surface. The rate of drying, and, consequently, the rate of removal of water, is dependent on the air speed, relative humidity, and temperature of the surrounding air (Delgado et al., 2003). The surrounding air conditions remain constant. The rate of drying will also remain constant. This stage of the process of drying is referred to as the "constant rate drying." As the removal of moisture from the fish continues, the drying effect continues. Eventually, the concentration of the moisture at the fish surface falls consequently, the movement of moisture to the surface also drops, and the drying rate slows down. This stage is referred to as the "falling rate drying" (Emokpae, 1979).

Both rates drying are under the influence of numerous factors. Notable is the relative humidity of the air. If the air is fully saturated with water vapor, drying will not take place. The relative humidity must be less than 100% for drying to occur. It is obvious, therefore, that the lower the relative humidity, the faster the drying rate. Increased air speed results in faster drying rates (Eyo, 1997). Distinct striate of air surrounds the drying fish. The layer nearest to fish is called the stationary layer. The stationary layer is saturated with water. Accelerated drying rates may be achieved to increase the surface area. If the environmental conditions, air speed, and temperature are conducive, drying is achieved faster (FAO/UN, 1969; Abowei & Tawari, 2011).

Smoking

Smoking is a popular traditional method of fish preservation in most developing countries. Smoking combines the effect of the destruction of bacteria by compounds in the smoke, such as phenols, and the cooking of the fish, since high temperatures will be generated. Smoked fish products have a 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, vapor, and volatile substances. The volatile substances are absorbed on the wet surfaces of fish during the smoking and produce the characteristic aroma (FAO/UN, 1969). As it is frequently seen in fish markets, properly smoked fish products are dark brown in color and are mostly nearly perfectly dried. This ensures that the shelf life is prolonged and the products get to the consumer in relatively good state (FAO, 1971a).

Salting

There are four standard methods for salting fish. These are brine, dry, kench, and pickle salting methods. In brine salting, the fish are immersed in a solution of salt in water. Where granular salt is rubbed into the surface of fish, the process is referred to as dry salting. Granular salt is also used in kench salting. In this process, the salt is rubbed into the surface of split fish, and the fish are stored with salt placed between each layer of fish. The liquid formed is not allowed to drain off the fish, which will eventually become covered with the liquid. The liquid is referred to as pickle. In pickle salting, the fish are packed in watertight containers with salt between each layer of fish. If the pickle formed does not cover the fish within 4 h, saturated brine is added to the fish so that it becomes immersed by the pickle. Otherwise, the fish may spoil (FAO, 1971b; Abowei & Tawari, 2011).

In brine salting, a saturated brine solution is used. Brine is prepared by dissolving 270–360 g of salt in one liter of water. Fish are then completely immersed in the solution. Due to uptake salt, the concentration in brine drops as consequence of water exuding from the fish. Fish may be stirred occasionally to enhance the uptake of salt. The latter may be eliminated if the brine is much (FAO, 1981; Abowei & Tawari, 2011).

In dry and kench salting, the fish are packed, surrounded by dry granular salt. The salt dissolves on the fish surface. The liquid, which exudes from the fish, does not cover the fish, thereby exposing the surface of the fish to air. It is therefore the practice to keep fish in saturated brine until the salt has been rubbed into the fish. Otherwise, fat oxidation, discoloration of fish flesh, and the development of rancidity ensue. During pickle curing of fish, the large quantity of salt used ensures that the salt is available in sufficient quantity to form the prickle in which the fish is eventually immersed. The person who now contains blood as well as other compounds in solution reduces fat oxidation and the development of rancidity (FAO, 2002; Abowei & Tawari, 2011).

Different fish species have different rates of salt uptake. Fatty and thick fish filets tend to absorb salt slowly. The thicker the fish filet, the slower is the rate of uptake towards the center of fish. Fresh fish may absorb salt readily but slowly (FAO, 1985; Abowei & Tawari, 2011).

Salt uptake by fish increases with increasing temperature up to an optimum. It is known that increased temperature also enhances fish spoilage. Salt replaces the water in fish. Therefore, there is less water to be reduced by drying. The higher the salt content, the less water needs to be removed. However, during sun drying, salted fish dry very slowly. The obvious reason is that salt tends to absorb water in the air surrounding the dry fish. In humid areas, excess salt may make absolute drying possible. It is recommended to begin the initial salting at reduced temperature up to an optimum (Igbeka, 1986; Abowei & Tawari, 2011).

Fermentation

Majority of the methods used in fish preservation involve the removal of water. These processes involve drying by the use of either heat or heat and smoke. The method that may be employed determines the end product flavor and texture. Fermentation methods have been widely employed to conserve or utilize surplus products. For fish products, this has been categorized into four divisions (Ita, 1999; Abowei & Tawari, 2011).

Division 1 includes those employing high salt concentrations containing salts in the range of 15 to 20% of the final product. The high salt content limits the protein intake by man. Consequently, this is mainly used as a condiment (Ito, 2005; Abowei & Tawari, 2011). In Division 2, strong mineral acids are employed as preservatives, and the acids include hydrochloric acid (HCL) and sulphuric acid (H_2SO_4). The method is confined to silage of forage crops, which have to be neutralized before feeding animals. The third division employs doses of organic acids. To produce fish silage, formic acid is added (Jenness, 1970; Abowei & Tawari, 2011).

The last division is that of generating organic acids by facilitating lactic acid bacteria growth. This division produces an apparently safe and easy to handle product. In the fermentation process, the enzymes within the fish are allowed to break down the protein within the fish under controlled factors. The end products of fish fermentation are stable and of normal temperature. The breakdown may be partial or entire. Three different products may emerge. The first type of product may retain the original form or large chunks of the fish. The end product may be a paste or the fish flesh may be reduced to liquid (Okonta & Ekelemu, 2005; Abowei & Tawari, 2011).

Many factors govern the end product of the fermentation process. These include the initial preparation of the fish, whether the fish was gutted or whole, the fat content of the fish, the amount of salt added and at what stage salt was added, and the temperature at which the fish is allowed to ferment (Olokor, 1997; Abowei & Tawari, 2011).

Fish preservation by fermentation is traditional. Small size fish that will not command premium prices in markets are generally used. Fatty fish, such as Brycinus and Lates species, when used, are burnt in earthen pots and allowed to ferment for a period ranging from 6 to 12 months. The end product is filtered. The bones are removed and the paste is sun dried. Fermentation by this method results in the incomplete oxidation of nutrients and the end product is alcohol and organic acid. The flavor and odor depend on the length the fish is allowed to ferment. Salt may be added (Al-Jufaili & Opara, 2006; Abowei & Tawari, 2011).

Mackerel species are also frequently fermented. They are gutted, cleaned of the gills, salted, and are placed in concrete tanks. Organic acid is added, and the fish remain in the brine for about four months. The end product keeps for up to one year. Where fermentation is allowed to continue for a very long time, sauces are produced. Sauces are liquids containing mixtures of amino acids and protein degradation products. They have very high salt content and may provide a good flavor. In preparing fish sauces, the fish is submerged in brine for up to 18 months. The ripened sauce color ranges from yellow to dark brown. The aroma and flavor are characteristic and determine the grade. Sauces are stable and may be kept for extremely long time (Oyelese, 2006; Abowei & Tawari, 2011).

The successful preservation of fish by biological fermentation method is dependent on the production of lactic acid. Lactic acid bacteria ferment the sugars present to organic acid, resulting in the lowering of PH. The low PH inhibits growth of pathogen organisms and putrefactive organisms. Since fish contains only small amount of fermentable carbohydrates, mixtures of malt, corn, or tapioca should be added (Abowei & Tawari, 2011).

Smoking equipment in use in Africa

Different smoking ovens and kilns are used in Africa for traditional smoking of fish. These include:

Cylindrical metal oven

The oven is usually constructed by joining together two opened, 44-gallon steel oil drums and cutting a stokehole at the base. The average diameter of the metal oven is about 115 cm, with a height of about 90 cm and a stokehole of approximately 40 x 40 cm. Iron rods are fitted about 60 cm above the base of the drum to serve as a support for the layers of fish. This oven has been used throughout African countries. It is light and portable but susceptible to rust and corrosion. It suffers from the same shortcomings as the cylindrical mud oven. In addition, since it is made of metal, it gives off considerable heat during the smoking process, to the discomfort of the processor (Adelowo et al., 1997; Nti et al., 2002).

Rectangular mud oven

This oven is rectangular in shape and constructed from mud. Thick iron bars are placed across the top of the base to support the layers of fish to be smoked. A stokehole is cut along one of the longer sides of the oven. The fish are arranged on pieces of wire mesh and placed on the supporting iron rods. Where more than one layer of fish is smoked, the layers are separated by sticks. This oven is used in different coastal towns and fish processing centers in West Africa. Disadvantages include: difficulty in handling the hot wire mesh loaded with fish during the smoking low capacity; loss of heat and smoke through the stokehole and round the layers of fish, resulting in inefficient fuel use; damage caused by the sticks separating the layers of fish; excessive handling of fish during smoking; pieces of fish falling into the fire, especially if the wire mesh is damaged; difficulty in controlling the heat (Adelowo et al., 1997; Nti et al., 2002).

Rectangular/square metal oven

This oven is normally constructed from 44-gallon steel oil drums, which are opened and joined to give a rectangular or square shape. Wooden battens are sometimes used for reinforcement. Thick iron rods are placed on top of the base to support the fish arranged on pieces of wire mesh. A large stokehole is cut at the base of the side wall. The disadvantages of this oven are similar to those of the rectangular mud model. It also radiates a great deal of heat (Adelowo et al., 1997; Nti et al., 2002).

Adjetey, altona oven

The oven originated in the former Federal Republic of Germany and was introduced in the 1970s by the German Volunteer Service to fish smokers at Biriwa, a fishing community in the Central Region of Ghana. The oven consists of a combustion/firing chamber constructed of burnt bricks, with a stokehole at the bottom of the front wall. The metal smoking unit, which is fixed by concrete on top of the combustion chamber, is enclosed and has a chimney. The fish are skewered through the eyes with metal rods and hung in the enclosed chamber for smoking. The skewering process removes the eyes of the fish, however, which is unacceptable to consumers. Disadvantages of the Altona oven included the high cost, which women could not afford, and the fact that hanging fish for smoking represented a departure from traditional smoking techniques to which processors were accustomed. Introduction of a modified version, known as the Altona-type oven, also proved unsuccessful (Adelowo et al., 1997; Nti et al., 2002).

Ivory coast oven

This type of oven consists of a square wooden frame to which aluminum sheets are nailed to form the sides. The fire chamber is made from one-and-a-half 44-gallon oil drums joined together, with one end of the drums opened. A hole is cut out of the upper part to allow the smoke and heat to pass through to the fish loaded on trays. A perforated metal plate is suspended above the hole to serve as a spreader. Three trays made from wooden battens with pieces of wire mesh nailed across them are placed on top of the framework. An aluminum sheet is used to cover the entire structure to retain heat and smoke. The oven was introduced to the Ivory Coast and a number of other African countries but not Ghana. The Ivory Coast oven was not acceptable to fish smokers at Lake Chad, as they did not have sufficient funds to cover the cost of the oven and purchase fish to fill it. The drum fire chamber was found to be cumbersome. The poor color of the smoked product and the high variability of the oven temperature also militated against the Ivory Coast oven (Nti et al., 2002).

Nyegezi oven

The Nyegezi oven, or fish-smoking kiln, was designed by the Natural Resources Institute in the United Kingdom and introduced first to Tanzania and later to Ghana in 1990. It was designed to heat fish solely by convection, isolating the fish from the fire to avoid direct heating by radiation. Air is heated in a furnace and diluted with air at ambient temperatures entering from ventilation holes at the side. After passing through the fish and heating it, the air enters a chimney, which channels it upwards. The suction created draws air into the furnace and dilution vents and maintains the current of hot air passing through the fish. The oven was originally designed to meet problems that were particularly in Tanzania: shortage of fuel, the fatty nature of the fish, and the need to prepare a product that could keep for several weeks at ambient temperatures. In Ghana, the circumstances were significantly different, and the oven did not offer any great fuel saving advantages in producing the type of cured fish required in Ghana (Adelowo et al., 1997; Nti et al., 2002).

The Chorkor oven

The Chorkor oven was an improvement of the traditional rectangular oven with a fixed surface. It was developed in the early 1970s by the Ghana Food Research Institute in collaboration with the women of Chorkor village and assisted by an FAO project. It consists of a combustion chamber and a smoking unit with a set of trays. The combustion chamber is rectangular, twice as long as it is wide, divided by a wall down the middle and with two stokeholes in front. The recommended standard measurements of the combustion chamber are: length, 225 cm; width, 112.5 cm; height, 60 cm; wall thickness, 12.5 cm; width and height of stokehole, 37.5 cm; depth of fire pit, 15 cm. The combustion chamber is the base of the smoker and is generally constructed from mud. The top of the wall must be flat so that the trays fit flush and no smoke or heat can escape through gaps. The smoker is designed so that the wooden frame of the trays rests along the midline of the base walls so that they are firmly supported and do not catch fire. The smoking unit consists of a set of 5–15 smoking trays, depending on the size and quality of fish to be smoked. The smoker has received wide acceptance in other African countries such as Benin, Nigeria, Kenya, Togo, Sierra Leone, and Tanzania (Adelowo et al., 1997; Nti et al., 2002).

Quality and safety status of traditional smoked fish

Traditional smoking techniques involve treating of pre-salted, whole or filleted fish with wood smoke in which smoke from incomplete wood burning comes into direct contact with the product. This had been found to contaminate smoked fish with polycyclic aromatic hydrocarbons (PAHs) if the process is not adequately controlled or if very intense smoking procedures are employed (Guillen et al., 1997; WHO, 2006).

Polycyclic aromatic hydrocarbons (PAHs) constitute a large class of organic compounds, containing two or more fused aromatic rings made up of carbon and hydrogen atoms and smoked fish is one source of PAH (Guillen et al., 1997). When fish is smoked, roasted, barbecued, or grilled, PAHs are formed as a result of incomplete combustion or thermal decomposition of the organic materials (WHO, 2006). Pyrolysis of the fats in the meat/fish generates PAH that become deposited on the meat/fish. PAH production by cooking over charcoal (barbecued, grilled) is a function of both the fat content of the meat/fish and the proximity of the food to the heat source (Phillips, 1999; Kazerouni et al., 2001).

Several analyses of charcoal roasted/grilled common fish have proven the presence of PAHs such as benzo[α]pyrene, anthracene, chrysene, benzo[α] anthracene, indeno[1,2,3-c,d]pyrene (Akpambang et al., 2009; Akpan et al., 1994; Linda et al., 2011; Ogbadu & Ogbadu, 1989). Most of these PAHs have been found to be carcinogenic while some are not (Bababunmi et al., 1982; Lijinsky, 1999; Fritz & Soos, 1980; Borokovcova et al., 2005). Emerole et al. (1982) screened for the presence of PAH in local foodstuffs available in Nigerian market. They discovered that appreciable amounts of benzo[α] anthracene and benzo[α]pyrene were found present in three varieties of smoked fish and smoked meat (suya) purchased from a popular market in Ibadan, Nigeria. In a recent study carried out by Olabemiwo et al. (2011) to assess the PAHs content of two smoked fish species available in Western Nigeria, it was found out that the sum of all PAHs in the smoked fish (*Claria gariepinnus* and *Tilapia guineensis*) ranged from 0.497 to 0.814 μg/kg and 0.519 to 0.772 μg/kg, respectively. High levels of PAHs have been reported to be associated with the dark colorations in intensively heated products. This was supported by Ova and Onaran (1998), who reported that the PAH levels were significantly higher in the fish skins than in the edible parts. Adeyeye et al. (2015b) also reported that traditional drum-smoked samples had high BαP and PAH levels (five out of six major PAHs [fluorene, anthracene, benzo (β) fluoranthene, benzo (α) anthracene, benzo (α) pyrene and benzo (ghi) perylene] exceeded the EU maximum permissible level of 5.0 μg/kg for BαP). Studies have reported the presence of aflatoxins; highly toxic compounds naturally produced by *Aspergillus flavus, Aspergillus parasiticus* and some microsclerotial species of *Aspergillus* section *Flavi* in fish and fish feed

(Adebayo-Tayo et al., 2006; Almeida et al., 2011; Barbosa et al., 2013). In addition, the hazardous effects of aflatoxin contaminated feeds on fish health and production have been documented (Jantrarotai & Lovell, 1990; Hussein et al., 2000; Shehata, 2003; Abdelhamid et al., 2007; Zaki et al., 2008). In spite of the available data on aflatoxin contamination of various foodstuffs and other livestock feeds, and the associated health implications, little or scanty data exists on the occurrence of *Aspergillus* species and aflatoxins in fishes in Nigeria and South Africa despite the fact that fishes are widely consumed in Nigeria due to their high nutrient profiles. Adebayo-Tayo et al. (2006) had reported the presence of Aflatoxin B1 and G1 in high concentrations in fish and concluded that smoked dried fishes stored for sale in Uyo markets, Nigeria were heavily contaminated with aflatoxigenic fungi. Fafioye et al. (2002) studied the fungal infestation of five traditionally smoked dried freshwater fish in Ago-Iwoye, Nigeria and isolated and identified 11 different fungal species, of which *Aspergillus flavus* was the most frequently encountered fungi on the fish species. Adeyeye et al. (2015a) reported the presence of *Listeria* monocytogenes in traditional drum-smoked fish samples from Lagos State, Nigeria. This poses risk to smoked fish consumers.

Conclusion

Although traditional smoked fish has been part of African menu for a long time, results from literature revealed that some of the smoked fish were of good quality standards. However, previous studies have revealed that traditionally smoked fish products from Africa may pose high level of potential risk due to the presence of high amount of carcinogenic PAHs, microbial contamination and the presence of aflatoxins; highly toxic compounds in the traditionally smoked fish products. This may pose high risks both chemical and microbiological to the consumers of smoked fish. Therefore, there is need for adequate process and quality control and regulatory monitoring of the product to safeguard the health of the consumers.

References

Abdelhamid, A. M., Salem, M. F. I., Mehrem, A. I., & El-Shaarawy, M. A. M. (2007). Nutritious attempts to detoxify aflatoxic diets of tilapia fish. *Egyptian Journal of Nutrition and Feeds*, *10*(1), 205–223.

Abowei, J. F. N. and. Tawari, C. C. (2011). The Classification, Facilities and Practices of Culture Fisheries in Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, *3*(10), 1096–1107.

Adams, M. R., & Moses, M. O. (1995). *Food microbiology*. Cambridge, UK: Royal Society of Chemistry, Thomas Graham House.

Adebayo-Tayo, B. C., Onilude, A. A., Bukola, C., Abiodun, A. & Ukpe, G.P. (2006), Mycofloral of Smoke-Dried Fishes Sold in Uyo, Eastern Nigeria. *World Journal of Agricultural Sciences*, *4*(3), 346-350.

Adelowo, E. O., Okomoda, J. K., Mdailbli, M., & Eyo, A. A. (1997). Improved smoking kiln on lake Kaiji, A report submitted to the Nigerian-German Kainji lake promotion project. New Bussa, Nigeria.

Adeyeye, S. A. O., Oyewole, O. B., Obadina, A. O., & Omemu, A. M. (2015a). Evaluation of microbial safety and quality of traditional smoked Bonga Shad (*Ethmolosa frimbriata*) fish from Lagos State, Nigeria. *Pacific Journal of Science and Technology*, *16*(1), 286–294.

Adeyeye, S. A. O., Oyewole, O. B., Obadina, A. O., Omemu, A. M., Adeniran, O. E., Oyedele, H. A., & Abayomi, S. O. (2015b). Quality and safety assessment of traditional smoked fish from Lagos state, Nigeria. *International Journal of Aquaculture*, *5*(15), 1–9. doi:10.5376/ija.2015.05.0015)

Agbelege, O. O., & Ipinjolu, J. K. (2001). An assessment of the exploitation and management techniques of the fisheries resources in the Nigeria portion of the lake chad. *Journal of Arid Zone Fisheries*, *I*, 89–98.

Ahmed, T. M., & Agbelege, O. O. (2007, November). An appraisal of the traditional fish handling and processing methods in Lake Chad. Proceedings of the Fisheries Society of Nigeria, 22nd Annnual Comference, Kebbi, Nigeria, pp. 46–51.

Akinola, O. A., Akinyemi, A. A., & Bolaji, B. O. (2006). Evaluation of traditional and solar drying system towards enhancing fish storage and preservation in Nigeria (Abeokuta Local Government as a case study). *Journal of Fisheries International*, *1*(2–4), 44–49.

Akpambang, V. O. E., Purcao, G., Lajide, L., Amoo, I. A., Conte, L. S., & Moret, S. (2009). Determination of polyaromatic hydrocarbons in commonly consumed Nigerian smoked/grilled fish and meat. *Fd Addit Contamination*, *26*(07), 1090–1103.

Akpan, V., Lodovici, M., and Dolara, P. (1994). Polycyclic aromatic hydrocarbons in fresh and smoked fish samples from the three Nigerian cities. *Bulletin on Environmental Contaminants and Toxicology*, *53*, 246–253.

Al-Jufaili, M. S., & Opara, L. U. (2006). Status of fisheries post-harvest industry in the sultanate of Oman: Part 1. Handling and marketing system of fresh fish. *Journal of Fisheries International*, *1*(2–4), 44–49b.

Almeida, I. F. M., Martins, H. M. L., Santos, S. M. O., Freitas, M. S., Da Costa, J. M. G. N., & Bernardo, F. M. A. (2011). Mycobiota and aflatoxin B1 in feed for farmed Sea Bass (*Dicentrarchus labrax*). *Toxins*, *3*, 163–171. doi:10.3390/toxins3030163

Anthonio, Q.B.O. (1970). *Fish marketing survey in the Kainji basin: Yelwa area study*. Ibadan, Nigeria: Nigerian Institute of Social and Economic Research.

Azeza, N. I. (1976). Fish handling processing and marketing in the Lake Chad Basin (North Southshores). Proceeding of the Conference on the Handling, Processing and Marketing of Tropical fish. Tropical Product Institute, London, UK, pp. 348–352.

Bababunmi, E. A., Emerole, G. O., Uwaifo, A. O., & Thabrew, M. I. (1982). The role of aflatoxins and other aromatic hydrocarbons in human carcinogenesis. In H. Bartsch & N. Armstrong (Eds.), *Host factors in carcinogenesis* (vol. 39, pp. 395–403). IARC Scientific Publication.

Barbosa, T. S., Pereyra, C. M., Soleiro, C. A., Dias, E. O., Oliveira, A. A., Keller, K. M.,…Rosa, C. A. R. (2013). Mycobiota and mycotoxins present in finished fish feeds from farms in the Rio de Janeiro State, Brazil. *International Aquatic Research*, *5*, 3. doi:10.1186/2008-6970-5-3

Bolaji, B. O. (2005, June). Performance evaluation of a simple solar dryer for food preservation. Book of Proceedings of 6th Annual Engineering Technology, Federal University of Technology, Minna, Nigeria, pp. 8–13.

Bonell, A. D. (1994). *Quality assurance seafood processing, a practical guide* (pp. 331). New York, NY: Chapman and Hall.

Borokovcova, I., Dofkova, M., Rehurkova, I., & Ruprich, J. (2005). Polycyclic aromatic hydrocarbons in the Czech Foodsstuffs in the Year 2004. *Chemical Listy*, *99*, 268–270.

Brownell, B. (1983). *A practical guide to improved fish smoking in West Africa*. New York, NY: UNICEF.

Clucas, J. I. (1982). Fish handling, Preservation and Processing in the Tropics, part 2, Report of the Tropical Development and Research Institute, G. 145, p. 18.

Davies, A.R. (1997). Modified-atmosphere packaging of fish and fish products. In Fish Processing Technology, 2nd ed., G.M Hall (Ed.), New York, NY: Chapman & Hall, pp. 200–223.

Delgado, C. N. Wada, M. Rosegranmt, S. Meijer, and Ahmed M. (2003). Fish to 2020. Supply and Delta, Nigeria and their aquaculture implications. *Journal of Fisheries International*, *2*(1), 22–66.

ECA. (1984). Women in the artisanal fishing industry in Senegal and Ghana. African Training and Research Centre for Women, E/ECAA/ATRCW/84/04.

Emerole, G. O, Uwaifo, A O, Thabarew, M. I and Bababunmi, E. A. (1982). The presence of aflatoxin and some polycyclic aromatic hydrocarbons in human foods. *Cancer Letter*, *15*, 123–129.

Emokpae, A.O. (1979). Organoleptic assessment of the quality of fresh fish. Nigerian Institute of Oceanography and Marine Research (NIOMR) Occasional Paper, No.12, pp. 1–4.

Eyo, A.A. (1997). Post harvest losses in the fisheries of Kainji Lake. A consultancy report submitted to Nigerian/German (GTZ) Kainji Lake fisheries promotion project, March, 75 p.

Eyo, E. A. (1985). Evaluation of colour and flavour of Tilapia smoked with different wood types. *Tropical Science*, *25*, 265–270.

Fafioye, O. O., Efuntoye, M. O., Osho, A. (2002). Studies on the infestation of five traditionally smoked-dried fresh-water fish in Ago-Iwoye, Nigeria. *Mycopathologia*, *154*, 177–179.

FAO. (1971a). Fishery Industries Division, Fishery Products and Marketing Branch, Equipment and methods for improved smoke-drying of fish in thet ropics. FAO Tech. Pap., 104: 27.

FAO. (1971b). Fishery industries division, fishery products and marketing branch a model fishery products quality control laboratory. FAO Fish. Tech. Pap., 107: 22.

FAO. (1981). The Prevention of losses in cured Fish FAO Fish Tech. papers, No. 219. 89p

FAO. (1985). Renewable energy source. FAO Technical Report Series, No. 8.

FAO. (1994). Utilization of Bonga (*Ethmalosa fimbriata*) in West Africa. Jallow, A. M., FAO Fisheries Circular No. 870, Fisheries Department 6, Marina Parade Banjul, The Gambia.

FAO. (2002, October). Workshop on promotion of sustainable commercial aquaculture in Zambia and Malawi, Lusaka, Zambia.

FAO. (2007). The state of world fisheries and aquaculture 2006. FAO Fisheries and Aquaculture Department. Food and Agriculture Organization of the United Nations, Rome.

FAO/UN. (1969). Report to the Government of Nigeria on fishing technology relating to river and swamp fisheries of Northern Nigeria Based on the work of W. Reed, FAO/TA Fishery Technologist.Rep.FAO/UNDP(TA), 2711: 90

Federal Department of Fisheries (FDF). 2007. Fishery Statistics of Nigeria. 4th Edition Federal Dept. of Fisheries, Abuja, Nigeria. pp. 49.

Fritz, W., & Soos, K. (1980). Smoked Food and Cancer. *Journal of Biblographic Nutrition and Dietetics*, *29*, 57–64.

Guillen, M. D., Sopelana, P., & Partearroyo, M. A. (1997). Food as a source of polycyclic aromatic carcinogens. *Reviews on Environmental Health, 12*, 133–146. http://dx.doi.org/10.1515/REVEH.1997.12.3.133

Hussein, S. Y., Mekkawy, I. A. A., Moktar, Z. Z., & Mubarak, M. (2000). Protective effect of *Nigella sativa* seed against aflatoxicosis in *Oreochromis niloticus*. Proceedings of Conference of Mycotoxins and Dioxins and the Environment, Bydgoszcz, pp. 109–130.

Igbeka, J.C. (1986, July). Evaluation of three types of solar dryers for Nigerian crops. Proceedings of a Workshop on Solar Drying in Africa, Dakar, Senegal, pp. 162–174.

Ita, E. O. (1999) *Enhancing potential fish catch in Nigeria's inland waters*. In: 13th Annual Conference of the Fisheries Society of Nigeria (FISON), 3–8 November 1996, New Bussa, Nigeria, pp. 14-29.

Ito, S. (2005). The Distribution Effect of compliance with food safety and agricultural health standards on small producers in developing countries. Proceedings for the Japan Society for International Development, pp. 113–116.

Jamin, D. M., & Ayinla, A. O. (2003). Potential for the development of aquaculture in Africa Naga. *26*(3), 7–13.

Jantrarotai, W., & Lovell, R. T. (1990). Subchronic toxicity of dietary aflatoxin B1 to channel catfish. *Journal of Aquatic Animal Health*, *2*, 248–254. doi:10.1577/1548-8667(1990)002<0248:STODAB>2.3.CO;2

Jenness, J. (1970). Fishermen of the Kainji Basin. Working paper No. 3., Kainji Lake Research Project. Rome: FAO, FI:3F/NIR, 24: 98.

Kazerouni, N., Sinha, R., Hsu, C. H., Greenberg, A. & Rothman, N. (2001). Analysis of 200 foods Items for benzo[α]pyrene and estimation of its intake in an epidemiologic study. *Food and Chemical Toxicology*, *39*, 423–436.

Kraseman, S. (1963). *Fish smoking, A torry-kiln operators handbook*. Torry Research Station, Department of Science and Industrial Research Min. of Technology, Edinburgh.

Lijinsky, W. (1999). The formation and Occurrence of polynuclear aromatic hydrocarbons associated with Foods. *Journal of Muttagenic Research*, *259*(3–4), 251–261.

Linda, M. N, Carboo P. D, Yeboah P. O, Quasie W. J, Mordecai A, Gorleku M. A and Darko A 2011. Characterization of Polycyclic Aromatic Hydrocarbons (PAHs) Present in Smoked Fish from Ghana. *Advanced Journal of Food Science and Technology*, *3*(5), 332–338.

Lydia, C. M. (1997). *So easy to preserve* (3rd ed., pp. 265). Co-operative Extensive Service, the University of Georgia College of Agriculture.

Neiland, A. E. (1991). An overview of fisheries research in the Chad Basin of Africa 1920 –1988 including a partially annotated bibliography, CMARE Res pap. No 45 (IV) 79.

Nti, C., Plahar, W., & Larweh, P. (2002). Impact of adoption in Ghana of an improved fish processing technology on household income, health and nutrition. *International Journal of Consumer Studies*, *26*(2), 102–108. doi:10.1046/j.1470-6431.2002.00210.x

Ogbadu, G. H., & Ogbadu, L. J. (1989). Levels of benzo(a)pyrene in some smoked ready-to-eat Nigerian foods. *Lebensmittel-Wissenschaft Und Technologie*, *22*(5), 313–314.

Okoko, A. C. (1996, October). Chorkor stove for fish smoking material and construction. Proceedings of the Refresher Training course for Fisheries, Uyo Akwa Ibom State, Nigeria, pp. 96–100.

Okomoda, J. K. and Alamu, S. O. (2003). *Application of participatory rural appraisal (PRA) techniques in the verification of fisheries data and trend on Lake Kainji*. In: 16th Annual Conference of the Fisheries Society of Nigeria (FISON), 4–9 November 2001, Maiduguri, Nigeria, pp. 53–58.

Okonta, A. A., & Ekelemu, J. K., (2005, November). A preliminary study of micro-organisms associated with fish spoilage in Asaba, Southern Nigeria. Proceedings of the 20th Annual conference of fisheries society of Nigeria (FISON), Port Harcourt, pp. 557–560.

Olabemiwo, O. M., Alade, A. O., Tella, A. C., & Adediran, G. O. (2011). Assessment of polycyclic aromatic hydrocarbons content in smoked *C. gariepinnus* and *T. guineensis* fish species available in Western Nigeria. *International Journal Basic Applications Sciences*, *11*(02), 135–150.

Olayemi, F., Adedayo, R., Muhummad, R., & Bamishaiye, E. (2011). The nutritional quality of three varieties of zobo (*Hibiscus sabadariffa*) subjected to the same preparation condition. *Plant Food Human Nutrition*, *6*, 10–15.

Olokor, I. O. (1997, January). Solar tent, an adaptable fish preservation technology in Kainji Lake Basin. In Kainji Lake Fisheries Promotion Project. A Promotion Project. A bulletin of the Nigeria/Traditional and Improved Fish Processing Technologies in Bayelsa State, Nigeria 548 German Kainji Lake Fisheries Promotion Project, New Bussa, Niger State, Nigeria.

Ova, G, & Onaran, S. (1998). Polycyclic aromatic hydrocarbons contamination in salmon-trout and eel smoked by two different methods. *Advanced Food Science*, *20*(5/6), 168–172.

Oyelese, O. A. (2006). Quality assessment of cold smoked, hot smoked and oven dried *Tilapia nilotica* under cold storage temperature conditions. *Journal of Fisheries International*, *1*(2–4), 92–97.

Phillips, D. H. (1999). Polycyclic Aromatic Hydrocarbons in the Diet. *Mutagen Research*, *443*, 139–147.

Shehata, S. A., Mohamed, M. S., & Mohamed, G. A. (2003). Reducing the toxicity of aflatoxin B1 by different adsorbents in fish. *Journal of Agricultural Science*, *28*(10), 7157–7167.

Stirling, H. P. (1985). *Chemical and biological methods of water analysis for aqua culturists, institute of aquaculture* (pp. 107–109). University of Stirling, Stirling, UK.

Tobor, J. G. (1984). A review of the fishing industry in Nigeria and status of fish preservation methods and the future growth prerequisites to cope with anticipated increase in production, NIOMR Tec. Pap. No. 17.

WHO. (2006). Polycyclic Aromatic Hydrocarbons. WHO Food Additives Series 55: Safety evaluation of certain contaminants in food. International Programme of Chemical Safety (IPCS), World Health Organization, Geneva, pp. 563–743.

Ye, Y. (1999). Historical consumption and future demand for fish and fishery products, exploration calculations for the years 2015, 2030. FAO Fisheries Circular No 949, Rome UNIFEM 1988, Fish processing, Food Cycle Technology, Source Book No. 4, 31 p.

Zaki, M. S., Sharaf, N. E., Mostafa, H. S., & Fawzi, O. M. (2008). Diminution of aflatoxicosis in *Tilapia niloticus* fish by dietary supplementation with fix in toxin and *Nigella sativa* oil. *American-Eurasian Journal of Agriculture and Environmental Science*, *3*(2), 211–215.