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FOOD QUALITY PERSPECTIVES IN AFRICAN FISH PRODUCTS: PRACTICES, CHALLENGES AND PROSPECTS

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1.0 Introduction

A fishery value chain includes the handling, processing, marketing and sales of fishery products to consumers; in the African context, the major types of fishes harvested from the waters of the Continent shelf and which feature in the fishery value chain include: cods, herrings, basses, redfishes, hakes, Jacks, mullets and saurines (FAO, 1998). The oceans, lakes and rivers are still the most important source of fishery products for Africa's fishing nations. Besides significant fish harvest from natural water courses, aquaculture is becoming an increasingly important fish production activity. Unlike other parts of the world, the African inland aquaculture industry does not largely culture prawns, cuttlefish, snails, lobster and other shellfish. However, where basket or cage farming is practiced in inshore coastal areas, crustaceans and shellfish are farmed on a small scale to cater for tourists and resident foreigners. However, farming molluscs and crustaceans has the potential for development into a prosperous commercial activity. Informal markets for the sale of fish are just as important and widely spread in Africa as they are in Asia. The preference for informal markets for fish supply is premised on the low-cost of the foods available at the markets, the extensive spread of markets and the availability of large amounts of similar and affordable commodities. Despite serving millions of customers daily, sellers in informal markets may not place much premium on food safety when they actually should in view of the real hazards to human health of not doing so. This is not to say that food safety is not a consideration by consumers when buying fish. In fact, the higher the income and level of education of the buyer, level of media interest in the conditions in the markets, the higher the demand consumers place on food safety. Enlightened African consumers therefore pay a premium price for safe and high quality fish. Generally, a limited variety of fishery products are available in African markets depending on whether the country is land-locked and depends on lakes and/or rivers or has access to an Ocean or Sea. Africa is surrounded by the Atlantic and Indian Oceans, Gulf of Aden, Red Sea and the Mediterranean Sea; many African countries are endowed with rivers and inland lakes, all of which provide a variety of fishes, some crustaceans and molluscs. Vigorous upwelling, convergence and mixing of cold and warm water currents off the Gulf of Guinea and the Atlantic Ocean enables the nutrient synthesis, thus improving nutrients variety and levels, making these zones rich fishing grounds; we therefore find rich fishing grounds off the coast of Morocco, Tunisia, Ghana, Guinea and Ivory Coast, Angola, Namibia and South Africa, making them some of the major fishing nations on the continent (Lokuruka, 2002). Aquaculture is receiving increasing focus as the natural fishery resources decline for various reasons including inappropriate exploitation, climate change, overfishing by distant fishing nations, environmental hazards on fishing grounds and low investment in modern fishing facilities and technology. The commonest fishery products available in African markets include crustaceans, molluscs, fresh and smoked fish, smoked, cured and sun-dried fish. Africa occupies a lowly position in global fishery products commerce, with its contribution being less than 5% by value (FAO, 2014). The quality of Africa's fishery products is highly variable; the determinants of their quality include the location of the fishery, season, the degree of pollution of the fishing ground, and the infrastructure available for handling and processing. The standards and requirements of hygiene, composition and other specifications for export products tend to be more stringent and rely mainly on the application of hazard analysis critical control point (HACCP) principles and general requirements of EUROGAP, the World Trade organization (WTO) and Codex Alimentarius Commission. Competent Authorities enforce these regulations in the fisheries industry often by adapting them to specific country situation. The above aspects are the content of this treatise focusing on fish product quality and safety in African fisheries.

2.0 The State of World Fisheries

In 2014, the value of fish traded internationally was US$136 billion, with Africa accounting for an approximate value of US$ 5 billion as its share (FAO, 2014). As the world human population grows, the demand for fish products and the pressure therefore on aquaculture to increase productivity rises. Aquaculture is experiencing notable growth in Africa, as capture fishery supplies either stagnate or generally decline. In 2003, the International Food Policy Research Institute and the World Fish Centre published 'Fish to 2020 –Supply and Demand in Changing Global Markets'. This report predicted that by 2020, sub-Saharan Africa would harvest 5.9 million tonnes of fish from capture fisheries and 132,000 tonnes from aquaculture, representing an annual growth rate of 2% and 6%, respectively. The largest fish producers in Africa include Egypt (just over 1 million tonnes in 2007), Morocco (894,000 tonnes) and South Africa (683,000 tonnes) over the same period. However, despite this progressive trend, Africa's participation in global fish trade remains insignificant. Africa was a net exporter for the period 1985–2010, but a net importer since 2011 in value terms, reflecting the lower unit value and progressive decline of fishery product exports (FAO, 2014). The European Union (EU) is the world's biggest importer of fish, other seafood and aquaculture products. Import rules for these products are harmonized across all EU countries. In the case of aquaculture products, a control plan on heavy metals, contaminants, residues of pesticides and veterinary drugs must be in place to verify compliance with EU requirements. For marine fishery products, scombrotoxin control for histamine levels and other biogenic and toxigenic amines products is a non-tariff additional necessity before exporting into the EU (Lokuruka, 2009, 2012). These requirements have resulted in market dis-orientation for African countries and therefore a reason for the Continent's limited participation in global fish trade.

2.1 African Fisheries in Global Context

Although some African countries are endowed with long coastlines and with fish resources from the various natural fishery product sources and fish farms, which contribute to food and nutrition security, livelihoods, exports and biodiversity, the continent accounts for approximately 8 million tonnes or 5.1% of the world's total fish production (FAO, 2007). This rose to 9.9 million tonnes of fish in 2010, of which 2.7 million (1/3) came from inland fisheries, 1.49 million tonnes from aquaculture and the rest from marine capture fisheries (FAO, 2014)**.** Per capita consumption of fish in Africa was reported to be 9.7 kg/year, a figure that is lower than the world average of 18.9 kg/year (FAO, 2012). The total value added by the fisheries sector to African economies in 2011 was estimated at more than US$24 billion, but this was only about 1.26% of total GDP of Africa (de Graaf and Gerabaldi, 2014). Fish trade is a mainstay of a number of African economies and represents a significant source of foreign exchange earnings, in addition to the fisheries sector's important role in income generation, employment, food and nutrition security. In 2011, the fisheries sector as a whole employed 12.3 million people as full-time fishers or full-time and part-time processors, accounting for the employment of 2.1% of Africa's population of 15-64 year olds (de Graaf and Gerabaldi, 2014). This grew from 3-3.5 million people directly employed in the sector in 2000-2004 (FAO, 2004). Of those employed in fishing in 2011, almost half were fishers, 42.4% being processors, while 7.5% were engaged in aquaculture. Women in the fisheries sector, account for about 27.3% of the total workforce; their level of direct involvement in fishing is 3.6 %, with 58% in processing and 4% in aquaculture (de Graaf and Gerabaldi, 2014). Women involvement in aquaculture and in fish processing is bound to grow. Fish is an important source of animal protein for many African riparian communities.

The export of a traded commodity normally requires quality management of the highest order. This is even more stringent for food products and more demanding for the highly perishable fish and fishery products. In addition to limited global participation in fishery commerce, Africa's capacity for intra-regional trade is still low. Official intra-African trade in fisheries products was just 11% of the continent's total trade between 2007 and 2011 (UNCTAD, 2013). Earlier, Essuman (1992) estimated that intra-regional trade in sub-Saharan Africa (excluding South Africa) for fish products was about 15 per cent of total fish production or 150,000 tonnes, and was valued at about US$200 million, although this has since increased. A number of factors contribute to Africa's low share of the global fishery markets and intra-African trade. These include inadequate trade infrastructure, deficient policy and institutional frameworks; tariff and non-tariff barriers as well as poor physical infrastructure, lack of capital or low investment in the sector, and, technology and information-linked bottlenecks. Use of inappropriate packaging materials or sometimes outright lack thereof, poor storage conditions at holding, processing facilities and markets, contribute to make the situation untenable. Tettey (1987) estimated that between 20 and 40% of fish harvested in the Africa region is wasted through spoilage. Lack of basic facilities like running water, electricity, ice, storage or refrigeration facilities at holding and processing sites contribute to this situation. Unhygienic processing and preservation methods such as drying of fish directly on the sand and mats, use of unclean fermentation tanks, the reuse of brine and similar practices, dirty packaging and transportation vessels, including traditional baskets and bags made of materials that cannot be kept in sanitary condition leads to product contamination and thereby subsequent spoilage. The result is considerable reduction in the shelf life of products during handling and in commerce. Most of these food products may also be unsafe to consumers. Where sanitation is poor, the main concern is infections from *Escherichia coli, Salmonellae,* sometimes *Staphylococcus aureus* and parasites (Roesel et al., 2015), although the concern in respect of parasites is insignificant when adequate thermal processing is assured.

High transport costs, complex and unaligned trade rules and poor market information also prevent African nations from optimizing social and economic benefits from intra-Africa trade. Lack of harmonization and/or enforcement of trade policies and sanitary regulations among African States, corruption, harassment at check points continue to hamper the development of intra-regional trade in fish products. A major challenge to the African Regional Standards Organization (ARSO) is the lack of uniform standards, regulations and conformity assessment regimes governing fish processing and trade on such basic parameters as moisture content, salt level, colour and olfactory characteristics, microbiological quality, insect infestation, packaging and texture of fishery products for the different markets. Quality inspection is mainly done on outgoing cured fish products at ports of exit for exports. However, locally produced cured products that are consumed internally are generally not subjected to stringent quality inspection; it can thus be argued that if the need for quality was enforced on products for internal markets, it could encourage a culture of producing quality products for export. Due to lack of conformity assessment procedures, official quality certificates tend to report on visual characteristics, and may therefore be regarded as subjective; adherence to quality characteristics demanded by export markets are crucial for penetration into international markets and for intra-African trade. The technical barriers caused by the International standards of food hygiene or the health regulations and quality compliance standards and procedures based on HACCP for fishery products adopted in developed countries, constrain Africa's participation in international fish trade. Indeed, despite the unilateral trade preferences the EU grants to African, Caribbean and Pacific countries (ACP), as well as the huge efforts made by African countries to comply with European standards, many still face difficulties in accessing the European markets mainly due to the stringent sanitary and phytosanitary standards and measures imposed by the EU. These constraints have a big impact on the region's share of international trade in fisheries products. Many members of the African, ACP group of countries are yet to develop these standards and have very little or inadequate technical infrastructure and budgets to meet the sanitary and safety standards laid down by the WTO or the EU. They therefore miss out on the benefits of trading with the EU, other trading blocks and partners who may be willing to accept their export products (Lokuruka, 2009, 2011). Two other important criteria for participation in international trade are meeting the fishery product traceability requirement and conformance to private standards. These latter are introduced through large retailers and supermarkets to cater to specific consumer demands. They add to the growing list of demands by importers on food, feed or food-ingredient imports from developing countries, to their further disadvantage.

2.1 Quality of fish products

Food safety is a scientific discipline that describes the handling, preparation and storage of food in ways that avoids the occurrence of food-borne illness. If appropriate procedures are not put in place in the food handling processes, severe health hazards including fatalities can result as a result of negligence. Food safety and quality are increasingly becoming important in international fish trade. Stringent conditions imposed by major fish-importing nations in the developed world, which take in 80% of global fish exports, give food safety priority over price as the main determinant of market access (Abila, 2003). Over 77% of fish exports originate from developing countries, which have limited capacity to invest in the rigorous fish safety measures demanded by importing countries (FAO, 2006). In the fishery industry, food safety is important because fish are particularly prone to pathogenic contamination, arising mainly from unhygienic handling during and after fish harvest, insufficient refrigeration, inappropriate processing, poor packaging and improper post-processing handling and storage. In fish-producing countries, failure to apply adequate quality and safety measures leads to losses at various stages of fish handling and marketing. Post-harvest fish losses include physical loss from poor handling and preservation; economic loss when spoilage occurs or when higher costs are incurred in reprocessing fish; and nutritional loss when fish is unsafe to eat (Abila, 2003). In addition, due to inadequate safety assurance measures, large quantities of fish may be processed into fish meal for feed when they could have been better used for human food. The economic costs of spoilage go beyond immediate product loss. The costs associated with fish-borne illnesses; the rejection, detention, and recalls of products in export markets; and the bad publicity for the affected country, are huge and should be avoided as regaining confidence of export markets is expensive and arduous (Abila, 2003). According to some estimates, the consumption of unwholesome fish and fishery products accounts for as much as 30% of all food-borne illnesses in the world (Iwamoto et al., 2010). It is estimated that nearly 10% (13 million metric tons) of the world's total fish production is lost as a result of spoilage, with quality losses accounting for more than 70% of the loss (FAO, 2010). Also, not all fishery losses and discards are spoiled (Gustavsson et al., 2011). In the Gambia, losses of 20-30% have been reported in traditionally handled and processed fish (Njai, 2000).

Considering the high global demand for fish and the scarcity of the natural resources, the colossal amount of waste alone justifies efforts to improve quality and safety in fishery products in commerce. If African countries put measures in place to reduce post-harvest fish losses, they would improve their export potential and earnings from international trade in fishery products, besides having more high value food available for their populations. When food is safe, its quality is also assured as the determinants of food quality are not altered. Fishery products are therefore deemed to be of prime quality when they are also safe to eat. Food quality refers to those characteristics in food that a consumer deems necessary to qualify the food as of the desired state for the purpose. These include physical characteristics such as size, organoleptic characteristics (smell, texture, taste, and flavour), chemical composition, microbial characteristics, and other characteristics which define the food (Lokuruka, 2002).

2.2 Fish Quality Assessment

Several methods are used to determine the quality and safety of fish products. These can be classified into sensory and instrumental methods. The latter comprise chemical, physical and microbiological methods. Sensory evaluation of fish quality is the scientific discipline used to evoke, measure, analyze and interpret reactions to characteristics of food as perceived through the senses of sight, smell, taste, touch and hearing (Lokuruka, 2002). Sensory methods have the advantage of being simple, cheap and rapid. However, they can be subjective as they are based on the assessment by individuals of their likes and dislikes. The subjectivity and bias can be reduced significantly by proper training and the use of proper descriptors and structured scaling (O'Mahony, 1986). Also, advances are being made in the development of instruments capable of measuring parameters such as texture and other rheologic properties, and microscopic methods combined with image analysis, are used to assess structural changes and "the artificial nose" is currently used to evaluate fish or fish product odour profile. Chemical methods rely on the measurement of metabolite(s) produced during fish storage, processing or distribution, to obtain a quantitative fish quality index. The most widely used chemical test is total volatile bases (TVB) or total volatile basic nitrogen (TVBN), which measures the content of trimethylamine (TMA) + dimethylamine (DMA)+ ammonia + other basic nitrogenous compounds associated with seafood spoilage. Other tests target the separate measurement of TMA, DMA, nucleotide catabolites (known as the %K-value) or biogenic amines contents (BA). The K or "freshness" index gives an indication of fish freshness during the early stages after capture, whereas TMA, TVB or BA gives this indication at later stages when bacterial spoilage starts. DMA is used to measure the quality of frozen fish. Also, oxidative rancidity is measured by evaluating the peroxide value (PV) during the early stages or the thiobarbituric acid-related substances (TBA-RS) during later stages. Fish product authentication relies on electrophoretic or DNA sequencing methods. Chemical methods are rapid, quantitative and reproducible. However, no one test is capable by itself of providing a picture of the full spectrum of changes that take place in fish metabolite breakdown or changes that lead to its perceived extent of spoilage. Physical methods involve the measurement of fish muscle pH, texture or electrical properties. These methods are rarely used because they are either not sufficiently reliable or require calibration depending on the fish species. Microbiological examination of fish aims at evaluating hygienic quality of fish, including temperature abuse, and the possible presence of pathogenic microorganisms in the fish. They mainly consist of the measurement of total aerobic bacteria also called total plate count, spoilage bacteria, and various pathogenic bacteria. These methods should be kept to the minimum as they are time consuming, costly and require technical skill to execute well for reproducibility and accurate interpretation of results. Several new rapid methods are being developed and marketed. They are based on immunological reactions (an example is the ELISA test, based on monoclonal antibodies) or genetic engineering (PCR and DNA-probes). Although all these methods mainly assess quality characteristics of fish and fishery products, quality and safety are correlated.

2.2.1 Quality of fresh fish

Lowering the temperature of fresh fish by icing as soon as it is harvested is a cost-effective method of fish preservation. Most African inland lakes and other bodies of water where fish is caught normally have temperatures in the range of 20-30^{o}C depending on the location of the fishery and the time of the year or season. The North and Southern Africa fishing nations of Morocco, Tunisia, Libya, Egypt, Mauritania and Algeria; South Africa, Angola and Namibia, respectively, experience periods of mild winters and hot summers; In the winters, temperatures can drop as low as 5^{o}C or lower occasionally but are mainly around 10^{o}C during most winters. During the winter periods of lowered environmental temperatures, handling fresh seafood and fish is more relaxed from the perspective of the fear of high fish losses from temperature-mediated deteriorative processes, although the temperatures rarely fall to 0^{o}C, implying that icing is still necessary. The opposite is true in summer when the temperature of the water and the air is elevated to the range of 20-26^{o}C. The West Coast fishing nations of Ghana, Ivory Coast, Angola, and Cape Verde; and those on the East coast including Kenya, Tanzania, Mauritius and Mozambique, do not normally experience winters and are blessed with tropical climates with temperatures normally at 25-35^{o}C throughout the year. These high tropical temperatures encourage fast deterioration of fresh fish if the handling and icing or the use of other fish cooling method is not applied almost immediately the fish are harvested. Fish from warmer, tropical environments tend to have higher bacterial loads than those from temperate regions or colder areas. Fish from polluted environments also carry higher bacterial loads for obvious reasons. Countries whose fisheries are on the coastline where major cities are located are likely to experience high pollution levels and the fish from such areas when washed with sea or lake water from near the shores can spoil quickly. The spoilage of fish gives rise to a variety of compound including TMA, TMAO, hydrogen sulphide, carbon dioxide, methylsulphide, dimethylsulphide, histamine, hypoxanthine, water, ammonia, and urea. Most of these compounds are from the breakdown of proteins, while lipid breakdown gives rise to volatile fatty acids, esters, alcohols, peroxides, etc. Icing and cold processing technologies depress the temperature of fish muscle. Bacteria normally proliferate faster at elevated temperatures so that cooling fish arrests the rate of bacterial growth and therefore keeps the fish in edible condition for longer. Cold processing of fish adds value to products when they are handled appropriately. It is more effective to cool tropical fish with ice than temperate fish as the increase in shelf life of iced tropical fish is considerable. Okeyo *et al*. (2009), Okeyo and Lokuruka (2010), found that the shelf life of iced Lake Victoria Nile perch was extended by as many as 4 days (with 4-6 hours of delayed icing). The shelf life of ungutted tropical Nile perch was as long as 22 days with normal handling in the Kenyan inland Lake Victoria fishery where a delay of up to 6 hours before icing is normal practice. It was also established that Nile perch and tilapia from the same lake fishery could be kept in prime quality condition for up to 25 and 30 days, respectively, when they were gutted and iced (Lokuruka *et al*, 2012, 2013). The tilapia in the above experiments was the farmed type; the immediate icing after removal from the pond was responsible for the longer shelf life in ice compared to the lake Nile perch. The shelf life extension and effect of gutting and icing on shelf life of tropical marine and inland fish has been demonstrated further with greater certainty (Lokuruka *et al*., 2013). However, Kapute *et al*. (2013) have shown the shelf life of fresh tilapia from Lake Malawi was lower at 16-18 days in ice. Where there is lack of capital to invest in ice plants or where local fishers and handlers are unwilling to purchase ice for fish preservation, the loss of value of un-iced fish products due to the high environmental temperatures of the tropics, is inevitable. The high environmental temperatures and the lack of use of ice and refrigeration are major contributors to post-harvest losses associated with tropical fisheries (Anihouvi et al., 2007), as fresh fishery products are highly perishable and their potential long shelf life is reduced if icing is delayed (Karungi e*t al*., 2004). A rare syndrome in African fisheries is scombrotoxicity. This condition can arise when consumers of scombroid fish fall ill due to consumption of scombrotoxin. Scombrotoxicity is a syndrome resulting from the consumption of spoiling or spoiled marine fish which have been exposed to abuse temperature. Scombroid fish are mainly from two families, the scombroideae and scombrososcideae. Mackerel and tuna fishes belong to the first family, while the black marlins, blue marlins, and herring belong to the second family. The consumption of the fish members of these two families that have been exposed to temperatures above 4ºC (abuse temperature) for longer than two hours after harvest may result in formation of scombrotoxin, a natural toxin that can give rise to a host of allergy-like symptoms; however, it was found out in experiments with some tropical potentially scombrotoxic fish, that the rate of formation of the toxin was lower in the tropical little mackerel (*Rastrellliger kanagurta*) and skipjack tuna (*Euthynnus pelamis*) as compared to the temperate mackerel (*Scomber scombrus*) when the fish were exposed to similar conditions of abuse temperature (Lokuruka and Regenstein, 2004). However, consumers need not worry about the likelihood of intoxication with scombrotoxicity when they consume spoiling inland lake-fish as it has not been exhibited in such fish. Where scombrotoxic fish are exported to the EU, care is normally taken by both the Competent Authority and the exporter to undertake careful examination during sampling of both raw material and processed product to confirm their quality and safety. This is done by exporters using rapid histamine kits. Kenya Fishery Regulations allow a maximum histamine content in fish flesh of 20 ppm (Government of Kenya, 2007). Tunas, mackerels, marlins, groupers and other potentially scombrotoxic fish are found in the marine catches of African fishing nations and therefore there is reason to believe in the potential of consumer intoxication from scombrotoxicity, where temperature abuse and delayed icing of such marine fish is a possibility (Lokuruka, 2009). The aquaculture inland industry is growing at an unprecedented rate in Africa. Aquaculture is expected to meet shortfalls in fish products for export and internal consumption. In addition, fish culture contributes to improved family incomes, employment and cost-effective utilization of land area, especially in areas where land is of low agricultural potential. In Kenya although both fresh water aquaculture and mariculture are practiced, the latter is insignificant and largely stagnant, so that the growth is in freshwater inland aquaculture. Kenya's aquaculture production of fish in 2000 was 1,000 metric tons, which rose to 12,000 metric tons in 2010 (Munguti et al., 2014), a figure that is expected to reach 20,000 metric tons by 2020, approximtaely 10% of total national fish production. The main fish species cultured include: Nile tilapia (*Oreochromis niloticus*-75%), the African catfish-*Clarias gariepinus*-21% of aquaculture production; lesser cultured fish include common carp-*Cyprinus carpio*, rainbow trout-*Oncorhynchus mykiss*, Koi carp-*Cyprinus carpio carpio*, and goldfish-*Carassius auratus*. Kenyan researchers have started culturing native species including *Labeo cylindricus* and *Labeo victorianus*. It has been demonstrated that when aquacultured fish was harvested straight from the pond and iced immediately within an hour of harvest, its shelf life was longer by 2 days compared to tropical lake-fish treated similarly (Lokuruka, in press), this may be related to the quality of the water in the two water bodies. It was also shown that when the aquacultured tilapia was gutted, its shelf life in ice was 32 days as compared to gutted Nile tilapia fish from the lake, which had a shelf life of about 25 days (Lokuruka *et al*., 2013). Nevertheless, the deterioration profile of tilapia fish from the two fish sources-pond and lake, appeared to be similar. The long shelf life of tropical fish is incomparable with the short shelf life of marine temperate fish which was demonstrated to be 11 and 14 days in ice for haddock and cod, respectively (Bamba, 2002), although the shelf life of other temperate fish in ice and in prime quality is reported as shorter averaging 8-9 days (Gorga and Ronsivalli, 1988). It is therefore clearly advantageous to ice and gut tropical fresh fish as the resultant extension of shelf life is considerable.

2.2.2 Quality of cured fish products

African fish processors sun-dry fish either without salt, rub in dry salt or brine to process low-grade fish products. They use these traditional technologies when the fish catch cannot be marketed immediately either due to glut, size or nature of fish species caught; fish products that are not salted and are sun-dried, predominate in the fisheries of the tropical climates of the arid and semi-arid areas of the Continent, where ambient air temperatures can be as high as 40-50ºC; when the fish to be dried are well split and opened up so as to expose a large surface area to the natural drying air, the loss of moisture is considerable. A common problem with sun-drying unsalted fish in the tropics is infestation with the dermestid beetles, although natural pyrethrin extracts have been used successfully to solve the problem in Kenya (Lokuruka, 2002). Cured fish products are low-value commodities often of inhomogeneous quality.

Nevertheless, cured products have the advantage of being storable for periods of up to one year or longer if they are free of insect infestation and are stored in sanitary conditions of less than 60% RH.

Smoking can extend the shelf life of fish products by at least two weeks depending on whether the product is hot or cold-smoked (Lokuruka, 2002). However, for these products to remain safe and in good quality appropriate packaging is required; a major concern in high temperature smoking of fish and other muscle foods is the deposition of high levels of polycyclic aromatic hydrocarbons (PAHs) on product surfaces. Some common PAHs include anthracene, pyrene, benzo[a] pyrene (BaP), and pentacene. These compounds are currently considered carcinogenic, mutagenic and teratogenic (Phillips, 1999; Kazerouni et al., 2001). Generally, the concentration and nature of PAHs in cooked meat products depends on the processing method, source of heat, the composition of wood, and the conditions of combustion (oxygen accessibility, temperature and time) (Knize and Felton, 2005; Onyango et al., 2012; Olatunji et al., 2014). Boiling does not deposit as much PAH as grilling or wood or coal-smoking of fish products. In low temperature smoking of whole fish or fillet, it is important that the product acquires the physical and organoleptic attributes desired by the consumer in smoked fish product. It was found in a study that the Nile perch from the Kenyan Lake Victoria fishery contained 7.46-18.79 µg/kg BaP in the hard-smoked fish and 4.17-11.26 µg/kg in the deep-oil fried fish (Muyela *et al*., 2012). These levels were higher than the 0.56-1.46 µg/g in all boiled, grilled and oil-fried fish (made up of hake, snoek, yellow tail, and angel fish) in a study by Olatunji *et al*. (2015). In another study, Olatunji *et a*l. (2014) established that levels of benzo(k) pyrene (BkP), benzo(a)pyrene (BaP), indo(1,2,3-cd) pyrene (IP) and Benzo(ghi) perylene (BghiP) were 0.64-31.54; 0.07-7.04, 0.09 -15.03, 0.51-46.67; and 0.01-5.11 µg/g in smoked, grilled and boiled meat products collected from processing facilities and restaurants in South Africa. In Ivory Coast, PAH levels in traditionally smoked fish products were generally found to exceed internationally-acceptable levels (Roesel et al., 2015). In experiments to determine the nature of PAH and PAH levels in meats in Kisumu City of Kenya, using traditional methods of cooking, it was established that open-air charcoal-roasting increased PAHs in goat and beef significantly ($P<0.05$) in all cases. The process also increased new PAHs in all these meats compared to levels in the raw meats (Onyango et al., 2012). Direct-heat charcoal roasted beef had a total mean PAH content of 17.88 µg/kg, compared with a mean of 1.39 µg/kg in raw beef, with the potent dibenz(a,h)anthracene being also detected. Direct-heat charcoal roasted goat meat had a mean total PAH content of 4.77 µg/kg, compared with a mean of 2.13 µg/kg in raw meat, with the potent benzo(a)pyrene being detected at a concentration of 8.84 µg/kg of the total mean PAH. Fried pork had a total mean PAH of 3.47 µg/kg, compared with a mean of 0.17 µg/kg detected in raw pork. Shallow-pan frying did not increase the PAH concentration in pork significantly ($P>0.05$). Roast beef had the highest individual PAH concentration of all the meats (5.03 µg/kg) and the highest total PAHs concentration (17.88 µg/Kg), both being higher than acceptable EU limits (Onyango et al., 2012). In related work, Olatunji *et al*. (2014), found out that levels of benzo(k)fluoroanthene (Bkf) were 2.57, 1.87 and 1.09 µg/kg in smoked, grilled and boiled beef, respectively; while levels of benzo(a)pyrene (BaP) were 5.34, 2.74 and

0.89 µg/kg in the smoked, grilled and boiled beef, respectively. In pork, BkF levels were 2.96, 1.37 and 1.01 µg/kg in the smoked, grilled and boiled products, respectively. BaP levels were 1.28, 1.75 and 0.94 µg/kg in smoked, grilled and boiled pork, respectively (Olatunji et al., 2014). BkF levels were 3.53, 1.29 and 1.19 µg/kg in the smoked, grilled and boiled chicken fillet, respectively (Olatunji et al., 2014). BaP levels were 2.91, 1.82 and 0.99 µg/kg in smoked, grilled and boiled chicken fillet, respectively (Olatunji et al., 2014). In summary, PAH levels in the unprocessed meats were not significantly different (P>0.05), but in processed meats, smoked meats (pork, chicken and beef) total PAH amounts were higher than in the grilled and boiled meats. It appeared that BGhip was most abundant in grilled meats, while IP was most abundant in unprocessed meats and BaP and BkF were most abundant in smoked meats.

Although hot-smoking drastically reduces the water content and the likelihood of bacterial growth in meat products, it raises the hazards associated with PAH and the health risks from long-term consumption of such food products. Current traditional processing technologies that produce low quality and low value-type of African fish products need upgrade in order to produce quality and safe products; this is critical for successful product penetration and competitive long stay in international markets.

2.2.3 Other Processing procedures

Canning fish is rare in African fisheries, due to the unavailability of adequate fish raw material to sustain the demands of a canning operation. Fermentation, a less common method of processing, relies on products of the metabolic activity of beneficial microorganisms to preserve and impart specific desirable flavours to a fermented fish product. During fermentation, the breakdown of proteins and other nitrogenous compounds results in the release of peptides, dipetides, and amino acids which influence the flavor of the mix. The release of various low molecular weight compounds is accompanied by the softening of muscle through the breakdown of collagen and other connective tissue proteins. Fermentation of carbohydrates results in the release of organic acids including ethanoic, propanoic and butanoic acids. Their release leads to a small depression of the pH of the ferment, which may contribute to an extended storage life of fermented products. In a study to extend the shelf life, acceptability and all-year availability of sundried *Rastineobola argentea*, known in the Lake Victoria fishery as “Dagaa”, spicing and smoking the tiny fish seemed to hold promise (Bille and Shemkai, 2006), despite the higher cost of the product when compared with the cost of the traditional sundried product.

2.3 Impact of current fish quality status

The stringent food safety regulations demanded by developed fish importing countries have important socioeconomic consequences in poor, fish-exporting countries of Africa. The costs to fish processing factories of restructuring their facilities to meet the demands of HACCP safety assurance programmes are significant. In addition, fishers need to invest in new, durable and sanitary fishing craft and on-board preservation facilities, while fish transporters must increase spending on refrigerated trucks and the use of ice. Private and public resources are incurred in retraining fishermen and other workers on hygienic fish handling practices (Abila, 2003). Governments must also invest in the establishment of laboratories to monitor fish quality and inspect fish value chains. To meet the EU fish safety requirements, many ACP countries continue to record improvements in the fish value chain to ensure the safety of fish destined for the EU market (Lokuruka, 2009). Designated jetties, holding warehouses and cooling facilities provide the much needed hygienic fish handling and preservation facilities. Fishermen are also supposed to ensure that their sea-going boats are equipped with adequate holds' space, equipment and facilities to hold the fish in hygienic conditions until they arrive at port. The provision of these conditions in the value chain tends to raise transport costs to bring fish to the final processing facilities, thus reducing fishers' net income. The new costs in the fish production and marketing chain make the final product too expensive for the domestic market; ultimately the fish must be exported in order to recover costs. Furthermore, the drive to earn foreign exchange means that all resources available to the fisheries sector are spent to meet export market conditions. The costs of producing high-quality fish for export largely fall on local communities, who also bear the cost of consuming unwholesome fish. Due to the frequent ban by the EU of Kenyan fishery products, Israel has lately become the most prominent single importer of Kenya's fish. Other markets have emerged in the Far East, North America, the Middle East, and other African countries. The EU is still the preferred market for fishery products from Kenya because of its relative proximity, which allows for greater profit margins. Thus, meeting safety standards in the EU is still important for Kenya and other fishing nations. African nations still face important challenges in implementing stronger food safety measures, especially in light of their small development budgets. They are, however, still pushing on with ensuring they meet these standards despite the high cost of doing so. Fortunately, since Lake Victoria has a near monopoly on Nile perch supplies, perch prices can be adjusted to cover some of the costs of the safety measures (Abila, 2003). Ultimately, a partnership between the government of Kenya and industry, with strong support from the EU, aims to ensure that food safety in the fisheries sector is improved.

2.3.1 Current Policy Initiatives in Fish Trade

African States are currently undertaking a number of measures to mitigate the negative impacts of stringent requirements for quality and food safety in international fish trade; these measures are designed to enable African fishing nations to seize the opportunities available in the sector. Improving the basic amenities for safe fish handling, processing, storage and trade, strengthening the policy implementation process and improving policy performance by building capacity in policy analysis and design, are currently being considered by a number of Africa's fishing nations; other areas of current focus are establishing policies with micro-level information on 'trade realities' and upgrading research and information systems, while creating and sustaining an enabling environment for fish trade through responsive and pro-active policy processes and negotiating international trade rules to access international markets; other policy issues being done or being considered include implementing at the national level, policies adopted at the regional level to facilitate the free flow of artisanally processed fish and fishery products; simplifying and harmonizing customs documents and tariff schedules to facilitate cross-border trade; and, setting and harmonizing sanitary and quality standards and conformity assessment regimes (in respect of packaging, application of HACCP principles, and labelling of goods) appropriate to the African context to facilitate greater trade. The good news is that despite the fact that Africa nations have for long acted individually on various issues of common interest, they are now, through these hard lessons, taking control of their destiny. For example, the Partnership for African Fisheries Initiative seeks to get all African states to speak as one voice on international policy issues and ensure fisheries is given proper recognition in policies on regional economic integration. The second Conference of African Ministers of Fisheries & Aquaculture in April/May 2014 endorsed the African Union Policy Framework & Reform Strategy for Fisheries & Aquaculture in Africa. This Policy Framework and Reform Strategy lays down the guiding principles for Africa aimed at: (i) increasing fisheries and aquaculture productivity, (ii) improving the profitability of fish enterprises, (iii) enhancing sustainability, (iv) increasing wealth generation, (v) raising social welfare, nutrition and food security, and (vi) strengthening regional collaborative management of the sector.

The 23rd Ordinary Summit in Malabo, Equatorial Guinea in June 2014 committed itself to triple, by the year 2025, intra-African trade in agricultural commodities (including fish) and services. The Summit endorsed the African Union Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa, and committed itself to accelerate trade by developing fish value chains, promoting responsible and equitable fish trade and marketing, in order to significantly harness the benefits of Africa’s fisheries and aquaculture endowments.

Developed countries also remain keen to work in partnership with Africa in these initiatives. For example the ‘Fish Trade for a Better Future’, a European Commission funded project being implemented by WorldFish, the New Partnership for Africa’s Development and the African Union Inter-African Bureau for Animal Resources (AU-IBAR) is aiming to strengthen value chains, and, with a focus on sustainability, give better access to intra-regional markets and subsequently improving food and nutritional security and incomes in sub-Saharan Africa.

Trade is a creator of employment, a food supplier, an income generator, and contributor to economic growth and development in several African countries. Domestic and intra-regional trade in fish has great potential to enhance regional integration, food and nutrition security. The program which is working to generate information on the structure, products and value of intra-regional fish trade and its contribution to food security in sub-Saharan Africa is intended to equip governments with the capacities needed to implement the African Union Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa. In addition, it has been designed to support the work of governments in implementing the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods. Evidently, access to international markets is dependent on Africa being able to offer products which meet quality and sustainability standards of the markets. ARSO’s interest is to ensure that the project supports the adoption and implementation of appropriate policies, fish certification procedures, standards and regulations by key stakeholders in intra-regional trade and recommendations on policies, certification procedures, standards and regulations, and embed them in national and regional fisheries, agricultural, trade and food security policy frameworks. To this end, as a member of the Working Committee, ARSO is set to:

- Identify and prioritize policy and regulatory options for promoting Intra-Regional fish trade in sub-Saharan Africa,
- Formulate regional policies, fish certification procedures, standards and regulations in selected areas that are critical for promoting intra-regional fish trade, and,
- Develop approaches for implementation and monitoring of these policies, standards and regulations

2.3.2 Fish Safety Legislation

Competent Authorities are implementing regulations required for exporting fish and fishery products. The Fisheries Departments or the Department responsible for fisheries matters controls fish quality through provisions of the relevant food legislation. E.g., the Kenya Fisheries Act and the Fish Quality Assurance Regulations, 2000 and 2007, respectively (Government of Kenya, 2000, 2007).The Kenya Bureau of Standards, which sets and supervises the attainment of standards for manufactured goods, has also defined standards for processed fish whether locally consumed or exported. As the EU is the largest trading partner for Africa and Kenya, its regulations for the fisheries sector are the most significant. Specifically the EU directives 91/493/EEC and 98/83/EEC are the most noticeable in this regard. These standards are enforced through "the competent authority" approved by the EU (mainly, the Fisheries Department) with periodic audits by EU inspectors. EU Directive 91/ 493/EEC lays down the requirements for handling and marketing fishery products. The directive is based on HACCP principles, and defines the practices governing fish production, handling, processing, packaging, and the transportation of fishery products destined for the EU. It also imposes strict standards regarding construction of buildings, equipment and storage tanks intended for holding fish prior to export. On-premise laboratories, strict record keeping, and accurate labelling are other requirements elaborated in the Directive. EU conditions also require that fish processors and exporters organize an industry-wide association to ensure self-monitoring on matters of fish quality. Kenya and other African Countries that export to the EU are developing institutions to meet all of the EU conditions on fish exports to its member states.

2.3.3 Prospects for Production of Quality Fish Products

As food trade and consumption become international, the opportunities to be exploited by those who can spot and seize opportunities to develop safe, acceptable and affordable products to satisfy discerning tastes as they emerge, are bound to rise. This will call for producers to adapt and/or modify current methods of handling and processing to produce new products for the emerging markets. African exporters have to satisfy the quality and safety requirements of these markets. Cooperation between competent authorities in African fish exporting countries is already underway in order to develop and apply cost-effective methods of quality and safety assurance in fishery products for emerging markets. Government agencies are providing the expertise to individual exporters to enable them meet the standards and other requirements as demanded by international markets. Markets differ in how stringent they prioritize quality specifications on imported fishery products. African exporters can take advantage of these differences in requirements to satisfy the demands of the various markets. As an example, the Middle East may not be as stringent as the EU in the application of the some of the specifications required by their consumers. Although any future outlook is difficult to estimate with accuracy, the general acceptance of the need to improve the quality of fishery products by African fishing nations is heralding an era of greater potential for trade with multilateral partners willing to engage on fishery products trade as long as their demands can be met. A current initiative is promoting high level Intra-regional fish trade policy dialogues to inform pan-African and sub-regional discourse. It is envisaged that the initiative will take advantage of the existing ARSO Platform which has so far produced:

- Two Fisheries Standards, African Regional Standard (ARS) 753-2013, General principles and criteria for sustainability and ARS 752-2013, Sustainability standards-Processes & Methods, Glossary and basic descriptions
- ECoMark Africa–the Pan-African, multi-sectoral eco-labelling initiative for Safety, Quality, and the Environment
- African Eco-labelling Standard, Fisheries-Sustainability and eco-labelling-Requirements; ARS 02 marine and inland capture fisheries, provides requirements for the sustainable harvesting of fish up to the point at which the fish are landed.
- Harmonized African Standards and Conformity Assessment for HACCP–internationally recognized system for reducing the risk of safety hazards.
- Harmonized African Sanitary/Safety Standards for Fish with a focus on: processing and post-harvest losses, handling, preservation, processing methods, distribution methods, moisture content, salt level, smell characteristics, packaging, texture, and labeling.
- The ARSO DISNET Trade Web Portal (arso-disnet.org) where African countries exchange trade and market information on products traded in Africa and their standards, regulations and conformity assessment regimes (ARSO CACO – www.arsocaco.org) requirements for the free flow of trade.

If Africa carries on with these initiatives, it will live to the expectations of the Africa Progress Panel led by Kofi Annan, former Secretary-General of the United Nations and Nobel Laureate and ten other distinguished individuals who advocate for equitable and sustainable development for Africa. Other recommendations with the potential to spur growth in trade in quality African fishery products in international commerce include:

- Developing the capacity for the appropriate capture, handling and cold chain storage and processing facilities on board fishing vessels,

- Developing and using internationally-acceptable standards when fishing, handling, processing and transporting fishery products to minimize loss of value and thus raising the acceptability of products by consumers, and,
- Increasing investment in research to solve problems on post-harvest losses, quality and safety of fish and fishery products.

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