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Review Paper

Processing and Quality Characteristics of some major Fermented Fish Products from Africa: A Critical Review

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Abstract

For many socio-economic and technical reasons, the fermentation is one of most important fish preservation methods used in many parts of the world and mainly the coastal regions of African countries in particular. The fermentation processes applied are generally indigenous and adaptable to the culture of the people. The main traditional fermentation techniques used as low-cost methods for fish preservation in African countries, the quality characteristics of the various end-products and the major constraints associated with the techniques used were discussed in this review. The lack of standardization of the processing methods and hygiene during processing, with their detrimental effects on the quality and the safety of the end-products are the major problems to overcome to ensure the promotion of fermented fish products sector in Africa. In this respect, there is a need for new areas of research focused on the standardization of traditional fermentation techniques to resolve the inconvenient associated with them and enhance further benefits of this technology. With increasing use of "bouillon cube" range of condiments in African countries, greater understanding of factors contributing to the safety and sensory quality of fermented fish products as perceived by the consumers would have significant commercial implications.

Keywords: Fish fermentation, ripening, salting, drying, microbial status, chemical characteristics.

Introduction

African countries require food processing technologies that will meet the challenges of peculiar food security problems in the continent. Such technologies should be low-cost to be affordable by the poor sectors of the community and should be able to address the problems of food spoilage and food borne diseases which are prevalent in the continent. Fermentation is one of important food processing technologies that meet these challenges[1]. According to Parkouda et al[2] fermentation is generally carried out to bring diversity into the kind of foods and beverage available; make otherwise inedible foods products edible; enhance the nutritional value; decrease toxicity; preserve food; decrease cooking time and energy requirements. The fermentation methods are indigenous to African cultures and have been used in many of these countries for centuries [1, 3, 4]. Of course these methods were artisanal in nature and obviously developed at home and improvements were based on the observations of actors. The activities are carried out mostly by illiterate women as the major actors; in general, there is little interest in knowing the role of microorganisms and the physical and chemical changes that occur in the products. What is recognized are changes in colour, odour and taste that result from modifications of the process or variation in ingredients[5-8].

Among the various fermented food processed in Africa, the fermented fish products are one of the oldest and most widespread used as condiments or main sources of protein of animal origin throughout the world[6,8-10]. According to Beddows[9] salted, fermented and sun dried fish is generally known as "fermented fish" since the processing methods usually involved salting, fermentation and drying. This combination of such processes is needed in tropical regions mainly because of climate and the extreme perishability of fresh fish. Indeed, a key factor limiting fish utilization is its extreme perishability due especially to bacterial and autolytic spoilage which usually occurs at the same time, after the death, during processing and sometimes during storage, and both contribute to normal spoilage processes[10-12]. As reported by Adams et al[11], fish flesh offers to microorganisms conditions of good nutrient availability coupled with a moderate pH and high water activity. In tropical regions, these conditions coupled with a high ambient temperature and unsanitary conditions cause fish spoilage within 12 hours[11,13]. The fermentation was also found to be an important method for fish preservation particularly because poor quality fish or unpopular species of fish are usually processed in this way. For this reason, fermentation helps to salvage fish which would otherwise have been thrown away.

Campbell-Platt[14] defines fermented foods as foods, which have been subjected to the action of microorganisms so that desirable biochemical changes cause significant modification of the food. In tropical regions the ambient conditions (high temperature, high humidity) provide ideal conditions for fermentation. Left alone, most foodstuffs will ferment naturally, some with desirable end results and others with less desirable and even poisonous end-products[15]. In this respect, the traditional fermentation of fish is qualified as natural or spontaneous fermentation. According to Gram and Huss[16] the fermentation of fish is brought about by autolytic enzymes from fish and microorganisms in the presence of salt. Various workers have reported the use of salt in fresh fish preservation as selective microbial agent[5,16,17].

Fermentation is also a low cost method of fish preservation using artisanal equipment which is readily available, easy to fabricate and repair. Therefore, processors do not need a large capital outlay to start operations. Rudimentary equipments such as basket, old barrels, earthenware pots, old nets, locally-made drying racks, mats, sack jute/ poly sacks and cans are the major items used. Generally, these items are locally available and affordable[6,8,18]. Consequently, a large number of people are engaged in fish processing by fermentation because of a ready domestic market and high demand for such product mainly at national and sub-regional levels, and sometimes at international level; therefore, there is a flourishing export potential[6-8,19].

With the exception of fisher men who provided fresh fish to processors, in most West Africa countries, females are the sole actors involved in the processing and the commercialization of fermented fish products[6,8,20,21]. However, in Central African countries such as Chad and Sudan, the processors are also males[6]. For most of processors, this activity constitutes their main source of income [6-8]. According to Essuman[6] more income is derived from fish fermentation than from smoking or drying in most African countries. This means that there is a potential for higher market value for superior quality fermented fish products. A higher market value for superior quality fermented fish products will improve the economic situation of the processors who adopt improved technologies for fermented fish processing; in addition the public will consume a healthy product**.** The present review examines the traditional processing methods in use in different regions of Africa and the quality of various end-products in both microbiological and physico-chemical aspects as well. The constraints limiting the promotion of fermented fish products in Africa were also raised.

The main African traditional fermented fish products and their processing methods

In most African countries, the traditional fermentation of fish is carried out in artisanal way and the processing methods seem to be the same from one country to another with however a slight variants. Three basic methods were identified for fish fermentation in Africa: fermentation with salting and drying, fermentation with drying without salting and fermentation with salting but without drying [6-8, 10] (figure-1) . The fermented fish products in Africa are habitually whole or cut in pieces, and are not a paste or sauce like in Southeast Asian countries[6,8]. Different local names are attributed to fermented fish products such as Lanhouin in Benin and in Togo[8,22], Momone, Koobi, Kako and Ewule in Ghana[6,20,21,23], Guedj in Gambia, Tambadiang, Yet and Guedj in Senegal, Djege and Jalan in Mali, Fessiekh, Kejeick, Terkeen and Mindeshi in Sudan, Dagaa in Uganda, Gyagawere, Adjonfa and Adjuevan in Ivory Coast, and Salanga in Chad[6,7,24]. The endogenous knowledge on processing methods of some major fermented fish products including Lanhouin, Momone, Guedj, and other are discussed in the following sections.

Processing of fresh fish into Lanhouin, Momone and Guedj

Lanhouin, Momone and Guedj are three fermented fish products produced in Benin, Ghana and Senegal respectively. There are all processed by fermentation associated with salting and drying. These fermented fishery products remain whole and firm after a fermentation period of 2 to 9 days[6,8,25] in contrast to some East Asian fermented fish products obtained after 3 to 9 months of fermentation, period after which, the fish is turned into paste or completely liquefied and gave a sauce [26, 27].

Lanhouin processing: The production of Lanhouin is laborious, time consuming and procedures are based on traditional knowledge on fermentation and experience. The raw materials used for processing include the fish and the salt. There are two different procedures employed for its production but apparently both lead to the same end-product[8]. The process is uncontrolled[8] and consequently there is no standard for the production. The duration of fermentation and storage problems are the main constraints raised by the processors themselves. However, based on observation, other major problems non-mentioned by the processors is the lack of hygiene during all the steps of processing leading to poor end-product in both microbiological and chemical aspects. According to Anihouvi et al[8], in the traditional procedure of Lanhouin processing, the first step is the dressing which consists in scaling, gutting and washing of fresh fish, followed by a period of 10-15 hours (overnight) of ripening, period during which the fish is left in a bowl without water (figure-1**a**). In some cases, the ripening step may occur before scaling and gutting, but this is not adequate because the fish is more subjected to autolytic spoilage resulting from endogenous enzymes of fish and microorganisms activities because of the presence of the guts which offer suitable conditions for microbial growth[28]. For the processors the ripening step is very significant because its influences the texture and the aroma of the end product. After the ripening step, the soft and dressed fish is usually washed with water from well or sea water due to deficiency of potable water. Such types of water are often polluted by domestic waste, making them a possible source of chemical and microbial contamination. After ripening, the fish is generally salted before been fermented. In this respect, the salt is introduced into the belly cavity, the gill and passed on all the fish body. The fish is salted once or twice depending on the duration of fermentation. For the first salting, the quantity of salt used varies between 20 and 35% of the weight of fresh fish while for the second one the quantity of salt accounts for approximately 15-25% of salt weight used in the first salting. The salted fish is then arranged in all kind of containers (basket, can, basket lined with cement, concret vat, and earthenware jar) and wrapped with jute sacks or clothes, or buried in a 2 meters depth hole and allowed to ferment[8]. The duration of the fermentation is 3 to 8 days, depending on the local conditions and the kind of product desired[8,19]. At the end of the fermentation, the fermented fish product is washed slightly to remove a part of salt remaining on its body. At this occasion, some drops of fuel may be added to the water to move away the flies during drying. The fermented fish Lanhouin is sun dried for 2 or 4 days to reduce its water content. At least 25 species of fish can be used to process Lanhouin but the ones mainly used include: Cassava croaker (*Pseudotolithus senegalensis*), Lesser African threadfin (*Galeoides decadactylus*), Atlantic bumper (*Chloroscombrus chrysurus*), kingfish/Spanish mackerel (*Scomberomorus tritor*) and Crevalle jack (*Caranx hyppos*).

Momone processing: The Momone is a Lanhouin-like fermented fish product from Ghana[18,21,23,29]. It is also widely used for its flavor enhancing properties. The processing of Momone is similar to Lanhouin one (figure-1**a**); it is usually carried out to salvage large quantities of fish which would otherwise have been discarded due to poor quality. The main species of fish used to process Momone include: catfish, barracuda, sea bream, threadfin (*Galeoides decadactylus*), Cassava croaker (*Pseudotolithus senegalensis*) barracuda (*Sphyraena* spp), jack mackerel (*Caranx hippos*), Scad mackerel (*Caranx rhoneus*) and kingfish/Spanish mackerel (*Scomberomorus tritor*)[6, 21]. For Momone processing, the whole fish may be used or cut into smaller pieces or split dorsally. The dressed fish is thoroughly washed and left overnight before salting or salted immediately after washing and allowed to ferment for 3 to 8 days after which the fish is dried on the ground, grass, nets, stones or raised platforms for 1 to 3 days[6,21]. The salt ratio generally used range between 15-40 % by fish weight. A second salting with ¾ of salt weight used in the first salting is applied when the fermentation is proceeded more than three days. Other Ghanaian fermented fish products such as Koobi and Ewurefua are different from Momone by the duration of fermentation which is 2 to 3 days for Koobi. In addition, the main fish used to process Koobi is *Tilapia*. Ewurefua is a product obtained from the fermentation of fish in tanks containing saturated brine from previous salting; the duration of fermentation varied from 12 to 24 hours[6] but this method can lead to cross contamination of the product due to the reuse of brine[30].

Guedj processing: Guedj is a Senegalese and Gambian traditional fermented fish product, used as flavoring agent and very appreciated by the local populations because of its exceptional flavor and taste[25]. For Guedj processing, the raw fish is often dressed, salted and allowed to ferment for about 2 to 3 days, followed by the drying step during which, the salted and fermented fish is put on raised platforms for about 3 to 5 days (figure-1**a**). In another procedure, the raw fish is left overnight to ferment before salting for 12-24 hours and drying.

Other African fermented fish products

There are other many fermented fish products which have received little scientific investigation (table-1). These products are: Malian Djege/Djadan, Ivorian Gyagawere/Adjonfa, Sudanese Fessiekh, Terkeen/Mindeshi and Chadian Salanga.

Djege/ Djadan processing: The local names Djege and Djadan referred to two Malian traditional fermented and dried fish products, with light brown colour and a mild fermented odour [6]. For processing, medium and large species of fish are washed, dressed, headed, salted and then put into water in an earthenware pot or oil drum and allowed to ferment for 12 hours (figure-1**a**). The fermented fish is then immersed in a solution of Gardona or K-Othrine for few minutes to prevent it from being attacked by blowflies during drying. Concerning smaller species, the fish is usually dried immediately after washing and fermentation occurs during drying[6]. Fish species such as *Tilapia*, *Clarias* spp., *Alestes* spp., *Schilbe* spp. and *Hydrocynus* spp. are commonly used to process Djege and Djadan.

Gyagawere, Adjonfa processing

Gyagawere, Adjonfa or Adjuevan are Ivorian fermented fish products used only as condiment but not eaten as food fish because of its strong smell[24]. For processing, the raw fish is dressed cut into pieces, when necessary and salted. The exudate from the fish is retained in the vat and the fish is immersed in this and allowed to ferment for 12 hours to 2 days according to the ambient temperature (figure-1**a**). In another procedure, the fish may also be left to ferment for about 12-24 hours before salting [6]. At the end of the fermentation, the fish is sun-dried for 2-7 days to achieve semi-dried final product or hard dried final product.

Fessiekh, Terkeen/Mindeshi processing

Fessiekh, Mindeshi and Terkeen are three Sudanese fermented fish products processed according to figure-1**c**. However unlike to Fessiekh and Mindeshi, Terkin or Terkeen is fish product which falls in category of sauces. They are all wet salted product, soft in texture with a strong odour[6,31-33]. The processing of Fessiekh is carried out in temporary sheds to provide shade or a cool environment. Species of fish such as *Alestes* spp. and *Hydrocynus* spp. are commonly used to process Fessiekh. In the processing procedure, the fresh fish is washed, covered with salt and arranged in alternate layers with salt either on a mat, in a basket or in perforated drums to ferment for 3 to 7 days depending on ambient temperatures. During this period, the liquid from the fish is drained off. Afterwards the fish is transferred into larger fermentation tanks where more salt and new batches of fish are added. The fermentation tanks are covered with jute sacks or polythene sheets and weights are placed on top to press the fish. The fish is then fermented for a further 10-15 days at temperatures ranging from 18°C to 20°C[6,33].

Salanga processing

Salanga is a Chadian fermented and dried fish product, light brown in color, firm texture and very strong odor. Usually, Salanga is made with fish of poor quality or not suitable for smoking. Salanga is processed according to figure-1**b**. Generally, the raw fish (*Alestes* spp) is dressed and washed. Larger species of fish are split dorsally and opened up. For the first variant of processing, the dressed fish is dried immediately after washing and fermentation takes place during drying [6]. Regarding the second processing variant, the fish is left to ferment for 12-24 hours before drying. In Salanga processing, salt is not used due to the scarcity and high cost.

Microbial diversity of African fermented fish products

Various authors have reported a large range of microorganisms involved in fish fermentation in African regions. According to Anihouvi et al;[17,34] a large number of microorganisms are associated to the fermentation of Lanhouin. The microbial population of Lanhouin consisted of a variety of Gram-positive and Gram-negative bacteria. The Gram-positive were largely halophilic types: *Bacillus* spp., *Staphylococcus* spp., *Micrococcus* spp., *Streptococcus* spp. and *Corynebacterium* spp. However, *Bacillus* spp. and *Staphylococcus* spp. were the predominant genera identified. Among these bacteria, *Staphylococcus* spp. and *Bacillus* spp. are expected to be found in fish from warm waters[30]. These organisms could also have come from the salt used to treat the fish[35]. *Streptococcus* and *Corynebacterium* species were present in very few numbers and this could be due to the high salt concentration. The high salt concentration leaves only salt tolerant microorganisms to survive; salt concentration up to 7% results in the inhibition of lactic acid bacteria[30]. Most *Bacillus* isolates were identified as *Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus megaterium*, *Bacillus mycoides* and *Bacillus cereus*; *Staphylococcus* species consisted mainly of *Staphylococcus lentus* and *Staphylococcus xylosus* (table-1). Similarly to Lanhouin, various species of microorganisms including *Bacillus, Lactobacillus, Pseudomonas, Pediococcus, Staphylococcus, Klebsiella, Debaryomyces, Hansenula* and *Aspergillus* involve in the fermentation of Momone[6,18,20,23,36] (table-1). But as for Lanhouin, the predominant ones were *Bacillus* spp. and *Staphylococcus* spp. Among the *Bacillus* species, *B. subtilis, B. licheniformis, B. megaterium, B. cereux* and *B. mycoides* have also been reported for Momone[18]. However in contrast to Momone, species such as *Klebsiella, Debaryomyces, Hansenula* or moulds such as *Aspergillus* were not detected in Lanhouin. The predominant microbial populations associated with Guedj fermentation were *Proteus* spp. *Shewanella putrefaciens,* and *Bacillus* spp[37]. Since the solid substrate fermentation of fish is usually an alkaline type, microorganisms such as *Bacillus* spp., *Staphylococcus* spp., *Micrococcus* spp, which constituted the predominant genera involved in Lanhouin, Momone and Guedj are expected[36]. The presence of similar genera of microorganisms has been reported for various other fermented products obtained by alkaline fermentation. For example, *Bacillus* species and coagulase negative staphylococci are known to be involved in various vegetable[38-41] and meat[42] products fermentation.

In contrast, the recent work carried out by Koffi-Nevry et al[24] on Adjuevan a fermented fish from Côte d'Ivoire showed that the fermentation is dominated by lactic acid bacteria, and the genera and species isolated and identified were *Leuconostoc lactis*, *lactobacillus fermentum*, *Pediococcus* sp. and *Streptococcus* sp.. These results agreed with the findings of various authors for fermented fish products obtained with a mixture of fish and carbohydrate source such as rice[11] but not for fish fermented without source of carbohydrate. Indeed, Asian fermented fish products are usually prepared by mixing fresh fish, salt and rice. For instance, Pla-ra and Pla-chom two fermented fish products from Thailand are prepared by mixing freshwater fish, salt and roaster rice and this mixture is allowed to ferment at room temperature for 6-12 months[43,44]. According to Tanasupawat et al[45] the microorganisms responsible for the fermentation of Pla-ra and Pla-chom were *lactobacillus, leuconostoc, Pediococcus, Enterococcus and staphylococcus*. Similarly, Yachai et al[44] isolated 11 strains of homofermentative, rod shaped lactic acid bacteria and five strains of heterofermentative, sphere-shaped lactic acid bacteria from Pla-ra and Pla-chom. They were identified as new species and named *Latobacillus acidipiscis* sp. *nov*. and *Weissella thailandensis sp. nov*. respectively. Such lactic acid bacteria are expected in both Pla-ra and Pla-chom, since these fermented fish products are prepared from a mixture of fresh fish and roaster rice. The roaster rice added to fish meat consisted a good source of carbohydrate, and consequently enhanced the development of lactic acid bacteria and the production of organic acids, mainly lactic acid which limited the survival of non-acid tolerant bacteria.

So, with the exception of *Streptococcus* spp. reported by Anihouvi et al[17] in Lanhouin, the results of Koffi-Nevry et al[24] disagreed with the findings of various authors who reported that the microbial populations of various African fermented fish products are mainly *Bacillus* spp. and Micrococcaceae since the type of fermentation is an alkaline one[6,17,18,23,36,46,47].

Main modifications occurring during the spontaneous fermentation of African fermented fish products

Biochemical changes: Various authors have studied the biochemical pattern occurring during the spontaneous fermentation process of fish. In this respect, changes in moisture, protein, free fatty acids, total volatile nitrogen, and histamine were observed during the fermentation period.

Table-1
Some major fermented fish products from Africa and microorganisms involved in their production

Types of fish	Products local name	Country	Fermentation duration	Microorganisms involved	References
Catfish, croaker, meagre, shark, mullet, skate, rays, triggerfish, horse mackerel, octopus, tuna, sole, Spanish mackerel, seabream, herring,	Gyagawere, adjuevan	Ivory coast	6 hours to 3 days with salting	Lactic acid bactria *Leuconostoc lactis Lactobacillus fermentum Pediococcus* sp, *streptococcus* sp	Nerquaye-Tetteh et al[20]; Essuman[6]; Koffi-Nevry et al[18]
Cassava croaker/Cassava fish , kingfish	Lanhouin	Benin	3 - 8 days with salting	*B. subtilis, B. licheniformis, B.megaterium, B. cereux, B. mycoides Micrococcus luteus., Staphylococcus lentus, Staphylococcus xylosus., Streptococcus; Corynebacterium spp.,*	Anihouvi et al[17]
Catfish, barraccuda, seabream, threadfin, croaker, grouper, bonito, mackerel, herrings, squid, octopus, bumper, snapper, ribbon fish	Momone,	Ghana	Overnight to 3 days with salting	*B. subtilis, B .licheniformis, B.megaterium, B. cereux, B. mycoides, Micrococcus luteus., Staphylococcus* spp, *Lactobacillus, Pseudomonas, Pediococcus, Klebsiella, Debaryomyces, Hansenula and Aspergillus*	Nerquaye-Tettch et al[20]; Yankah[23]; Oronsaye[36] Essuman[6]; Sanni et al[18]
Carp, threadfish	Djegue, jalan	Mali	Overnight, no salting	unknown	Essuman [6]
Alestes Nile perch, parch	Aku	Ndokwa-East in Southern Nigeria	Overnight, with little salt	unknown	Azeza[99]; Nwabueze and Nwabueze[100]
Mackerel, seabream, threadfin, croaker, mullet, catfish, meagre, herrings, skate, rays, shark, Bonito	Guedj, tambadiang, yeet	Gambia, Senegal	Overnight to 2 days with salting	*Proteus* spp., *Shewanella,putrefaciens, Bacllus* spp	Essuman[6]; Diop[37]
Tiggerfish; Nile perch, Tilapia, parch	Fessiekh, Terkeen/ Mindeshi	Sudan	10-20 days with salt	unknown	Essuman[6]
Alestes Nile perch, parch	Salanga	Chad	12-24 hours with salting or 4 to 5 days without salting	unknown	Essuman [6]

Changes in pH, moisture, proteins and free fatty acid: The physico-chemical characteristics of some of the African fermented fish products discussed in this review are summarized in table 2. The pH values of Lanhouin are generally above[78,17,34]. Similar higher values of pH were reported on Momone[18,20,21,23]. In contrast for Adjuevan, pH values ranging between 5.2 and 6.10 were reported by Koffi-Nevry et al[24]. No literature on the recommended pH range of African fermented fish products is available. Similar fermented fish known as Pedah siam is processed in Thailand. For this product fresh fish is fermented unlike the partially deteriorated fish used for Lanhouin, Momone, Guedj or other fish products obtained by spontaneous fermentation in solid substrate. The standard pH requirement for Pedah siam is 6.0 - 6.4 with a pH of 6.5 or higher considered as indicative of poor quality[48]. But, since in the processing of African fermented fish products, a seemingly deteriorated fish must be used, the high pH values around 7 or above 7 obtained is expected and may be considered as the usual pH value for these fermented fish products. Such pH fit well with the strong but not repugnant smell which characterise the majority of African fermented fish products[6,18,49].

It was observed that during fermentation, the moisture content of fermenting fish varied considerably according to the type of fish (lean or fatty fish), the duration of the fermentation, the quality of salt used and the amount of salt as well. For example, Anihouvi et al[49] observed that the moisture content in cassava fish decreased from 73 to 46.9% after 8 days of fermentation for Lanhouin, while a decrease range from 78 to 57.6% was noted for Momone (table- 2). The decrease in moisture content become emphasize during the sun drying which is the final step of the processing except for certain types of wet fermented fish products. Sun-drying step is not always sufficient to stabilize the fermented fish products. This step which is normally combined with salting (by addition of NaCl) has dual effects such as the lowering of the water activity (aw) level and a specific inhibitory effect on the growth of some species of microorganisms through the Na^+ ion. So, the two steps (salting and drying) are interrelated to reduce the moisture sufficiently. The decrease in moisture is due to osmotic migration of salt into and water out of the fish[30,50]. Decrease in moisture led to increase in salt content and consequently extend shelf life of the products[30,51,52].

Variation in protein content was also observed and depends on enzymatic and microbial activities during the fermentation. Decrease in protein content has been reported by various authors during the spontaneous fermentation of various fish products including Lanhouin, Momone, Guedj and Adjuevan and other fermented fish products[6,21,24,49]. In this regard Anihouvi et al[49] reported that the protein content in cassava fish decreased from 75.6 to 54.8 % dried weight basis (dwb) after 8 days of fermentation during Lanhouin processing; this revealed a loss of 27.5 % of the initial protein content of fresh fish. Similar decrease has also been reported by Abbey et al[21] for Momone, a Lanhouin-like fermented fish product. Regarding Adjuevan, protein content of the fermenting fish decreasing from 53.93 to 25.66 % was observed[24]. This gives a protein loss of 52.4%. The decrease in protein content of the fermenting fish samples was explained by proteolysis effect during which proteins are broken down into peptides and amino acids which could be lost in the exudates (extracted water) from the fish. In this respect, Abbey et al[21] have reported a protein content of 12 % in the exudates collected during the fermentation of Momone.

Free fatty acids (FFA) value is a measure of the extent of oxidative deterioration in oily fish, but it can fall further at latter stages of fish spoilage[53]. A high level of FFA is characteristic of product that have undergone both microbial and biochemical spoilage[30,54]. FFA contents ranging from 11 to 14% oleic acid, and 27.2 to 36.6 % oleic acid were recorded on market samples of Lanhouin obtained from cassava fish (*Pseudotolithus sp.*) and king fish (*Scomberomorus tritor*) respectively. Similar increase in FFA contents during the fermentation of Momone and the ripening of salted Anchovies has also been reported by Abbey et al[21] and Hernández-Herrero et al[55]. The increase in FFA showed that salt did not inhibit lipases responsible for the liberation of free fatty acids. Such liberation has been indicated by Roldan et al[56] and Perez-Villareal and Pozo[57]. This may indicate that greater proportions of unsaturated fatty acids were liberated and were subjected to oxidative splitting at the double bonds. The resulting substances, mostly ketones and aldehydes, appear to be largely responsible for flavor, odour and taste of the fermented fish products[58].

Changes in total volatile nitrogen and production of biogenic amines: Chemical compounds such as total volatile nitrogen (TVN) and biogenic amines (e.g. histamine) which normally did not exist in fish muscle are mostly formed in the fermented fish products as the result of autolysis and microbial spoilage of fish during processing[6,49,59-63]. In this respect, total volatile nitrogen (TVN) contents varying between 294.5-374.5mg N/100g and 295.4-394.8 mg N /100g were recorded in Lanhouin and Momone respectively[21,34,49]. High level in TVN resulted from the formation of nitrogenous basic compounds, such as ammonia, due to the protein degradation through microbial and enzymatic activities[12]. Similarly histamine contents ranging between 17.4-39.7 mg/100g and 101-167 mg/100g have also been reported for Lanhouin and Momone respectively[21,34] (table-2). In general, these levels of histamine content exceeded the recommended level of 20 mg/kg fish muscle stipulated by the Food and Drug Administration (USA), the European Economic Community (EEC) and the Australian Food Standards Code[64-66]. Investigations on fish sauce, fish paste and dried fish imported from Asian countries confirmed high levels of biogenic amines[67]. Dried fish products contained 80.3mg/100g of histamine were also reported by Wootton et al[67].

Formation of aroma compounds: The general use of fermented fish product as condiment in many African and Asian countries is due to their pleasant taste and peculiar aroma. Thus

Anihouvi et al[49] have reported the presence of 94 aroma compounds in Lanhouin samples fermented over eight days of fermentation period. These compounds mainly consisted of aliphatic hydrocarbons, aromatic hydrocarbons, esters, ketones, acids, alcohols, amines, amides, aldehydes, pyrroles, thiazoles, furans and phenols; however aliphatic hydrocarbons, aldehydes, alcohols, esters and ketones comprised the majority of them. Aliphatic hydrocarbons, aldehydes and alcohols mainly derived from oxidative deterioration of polyunsaturated fatty acids (PUFA)[68-70] while ketones derived from amino acid degradation[71,72]. The major groups of compounds detected in Lanhouin have also been reported by other workers on various fermented fish products, mainly for the South Asian ones[73-75]. The development of such compounds in fermented fish products is attributed to both enzymatic and microbial activity[68,69,75]. Various species of microorganisms including *Bacillus spp*., *Staphylococcus spp., Micrococcus spp.,* and some gram-negative species, such as *Pseudomonas spp*. have been evoked in the development of volatile aroma compounds[10,17,76]. In other studies, the development of various aroma volatile compounds was also attributed to the metabolic activities of *Bacillus spp*. during the fermentation[77-79]. But for other authors the development of specific aroma in fermented fish sauces and pastes is not due to the action of microorganisms[9,80]. Beddows[9], isolated halotolerant organisms such *Bacillus spp*. and used them in pure culture but none of them produced the typical fish sauce aroma. Adam[80] also concluded that microorganisms played little or no part in aroma production. So, further studies focused on the role of predominant organisms on chemical changes and aroma development during the fermentation of fish products need to be undertaken.

Health hazards associated with the consumption of fermented fish products: A number of practices observed during processing of traditional fermented fish products constitute health hazards to consumers. These practices are related to the processing technique itself, the environment in which the fish is processed, the waste disposal of the fish, the unhygienic nature of processing materials and improper packaging of the product as well. During the dressing step, the fish may be held under the foot on the ground. This practice can lead to microbial contamination of fresh fish. The lack of potable water constitutes a problem during washing step. Thus, water from lagoons, rivers, lakes or sea is generally used to wash the fish[6-8,37]. These water bodies are often polluted by all kind of waste making them a possible source of chemical and microbial contamination. The traditional fermented fish products are often dried on the ground or on dirty materials. Drying fish in such conditions is source of contamination with sand and microorganisms. The fish is subjected to blowflies and other types of insects attack especially for unsalted fish. These types of problems led to the illegal use of substances such as petroleum and insecticides[6 8,21]. Processors usually packaged the products in various types of traditional containers or recycled containers during fermentation, storage and when transporting the product to the market. The unhygienic nature of these materials could be potential sources of microbial or other types of contamination. Consequently, in the artisanal fish industry where technology and standard are very low, fermented fish products could be considered as potential vehicles for transmission of food borne diseases. Investigations on various fermented fish products confirmed high levels of biogenic amines mainly histamine[8,21,67]. When the foods are contaminated with bacteria containing decarboxylase enzymes, these free amino acids undergo decarboxylation to produce biogenic amines[60,61,63]. For instance, histidine is decarboxylated to produce histamine; lysine is decarboxylated to produce cadaverine and putrescine[62,81,82]. In general, most amines are heat stable and some decarboxylases remain active even after pasteurisation. This implies that the amount of amine once formed will not be reduced during cooking. Thus, despite a lack of information on food poisoning caused by African traditional fermented fish products, there is a potential for sporadic amine poisoning. Ingestion of food containing small amounts of histamine has little effect on humans, but in larger amounts histamine can be toxic[62,83,84]. The incubation period of histamine poisoning is short; poisoning effects can occur within several minutes to a few hours following ingestion of a meal containing high levels of histamine[62,83,84]. The duration of illness is usually short and, in most cases, symptoms such as flushing, oral burning or a blistering sensation and perspiration pass within a few hours. Less frequent symptoms include vomiting, diarrhoea, stomach pain, headaches, swelling of the tongue, facial swelling and dizziness[85,86]. In conclusion, despite a lack of official reports on food poisoning caused by the consumption of fermented fish products, there is a potential for more than just sporadic amine poisoning, since that many food poisoning cases in African countries do not reach official channels.

Used of starter culture to control the fermentation of fish products: The traditional fermented fish products are produced by spontaneous and largely uncontrolled fermentation. Like other African fermented food products, fermented fish are currently produced largely on a traditional small-scale basis under highly variable conditions[6-10,18]. The quality of the product is unpredictable and shelf-life is short. With increasing urbanization and demand of high quality traditional products, there is a need for controlled fermentation process and to minimize the variation in product quality encountered during the spontaneous fermentation at cottage industry level. In this respect, the use of starter cultures to promote the processing of fermented fish products is necessary. The use of starter cultures to promote traditional processing has been suggested by various workers[6,87-91]. A starter culture can be defined as a microbial preparation of large numbers of cells or at least one microorganism to add to a raw material to produce a fermented food by accelerating and steering its fermentation process[87]. According to Yin et al[92] the use of starter cultures to ferment minced mackerel could suppress the growth of spoilage bacteria and pathogens, and substantially inhibit the development of volatile basic nitrogen. Rapid decline of pH not only gives the products unique lactic acid flavor, but also increases firmness, texture and palatability due to the acid denaturation of muscle protein[93]. The formation of biogenic amines in fermented fish products has been reported by various authors[8,21,49,82,94]. In this respect, the use of amine-negative starter cultures to prevent biogenic amines formation has been suggested by Taylor and Speckhard[95] and Holzapfel[87]. However, there is a controversy about the inhibitor effect of starter culture on biogenic amines formation. According to Rice[96] the use of *Pediococcus cerevisiae* and *Lactobacillus plantarum* caused no difference in tyramine contents. Bauer et al[97] also reported that the addition of starter culture did not affect the formation of biogenic amines. Furthermore, work carried out by Maijala et al[98] showed that amine–negative *Pediococcus pentosaceus* added as starter culture decreased the levels of histamine, tyramine and cadaverine formed during ripening of dry sausages. These results therefore support the use of starter culture to decrease formation of biogenic amines. It is expected that, the use of the starter cultures for fish fermentation may also reduce the fermentation time, enhance inhibition or elimination of food borne pathogens, and improve shelf life and sensory quality of products in terms of taste, aroma, appearance and texture. Many of these desirable attributes are associated with spontaneous food fermentation; however the extent and quality of products are not predictable or controllable.

Conclusion

Through this review it appears that the use of fermentation as a low-cost method of fish preservation is commonly practised in Africa and other parts of the world and remote areas where access to sophisticated equipment is limited. Following, critical review of the entire process, a summary of the main steps for fermented fish production and major associated constraints has been developed. This provides comprehensive knowledge which will facilitate the improvement of the traditional operations to a level where it can be integrated into *the* formal sector of the food industry in the processing countries. The lack of standardization of the processing methods and hygiene impair the quality and the safety of the products as well. In addition packaging of the end-products needs to be improved. The development of local food industries through the Improvement of traditional fermentation technologies is one of the appropriate solutions to enhance value-added products and the market share of traditional products. In this regard, the culture, the culinary traditions and the current level of development of the processing methods in each concerned country should be taken into account. This is necessary for the success of any action that will be undertaken for the improvement of traditional Lanhouin technologies.

Table- 2
Physico-chemical and nutritional composition of some fermented fish products from Africa

Type of fish	Products name	Content (per 100g sample) (wwb)[1]									pH	Aw	References
		Moist	Prot	FFA	NaCl	TVN mg	Hist mg	Ca mg	Fe mg	P mg			
Cassava croaker/ Cassava fish	Momone	57.6	26.2	20.8	5.7	318.3	130.5	-	-	-	7.5	0.65	Essuman[6]; Abbey et al[21]; Anihouvi et al[34, 49]
	Lanhouin	51.1	26.5	12.5	7.3	294.5	21.4	-	-	-	7.3	0.71	
Spanish mackerel/ king fish	Lanhouin	56.6	24.6	31.9	5.2	374.5	33.1	-	-	-	7.6	0.77	Essuman[6] ; Abbey et al[21]; Anihouvi et al[34]
	Momone	54.8	25.2	30.8	5.8	336.1	143.0	-	-	-	7.8	0.73	
Atlantic bumper	Adjuevan	70.6	25.6	-	1.7	-	-	5.3	-	4.1	5.7	-	Koffi-Nevry et al[18]
Tigger fish	Turkeen	40.0	23.8	-	-	-	-	410	78	160	6.1	-	Mohammed[33]

[1]Wet weight basis; Moist: moisture; Prot: protein; FFA: free fatty acids; TVN: total volatile nitrogen base; $A_{w:}$ water activity; Hist: histamine; P: phosphorus; Ca: calcium; Fe: iron

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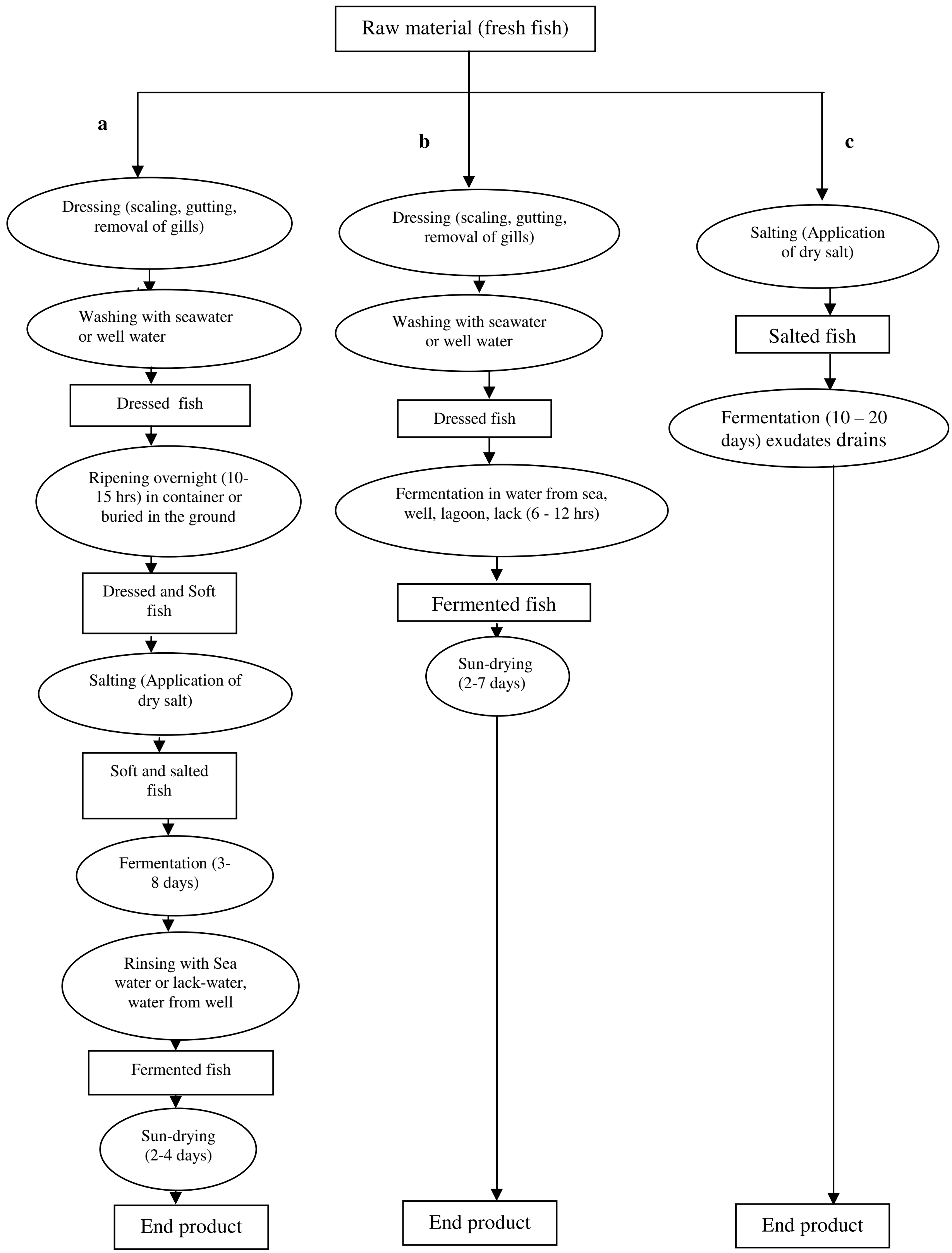

i. Fermentation with salting and drying[6,8], ii. Fermentation and drying without salting[6, 25], iii. Fermentation with salting without drying[6, 7].

Figure-1
Flow diagram of traditional processing of fermented fish products in Africa