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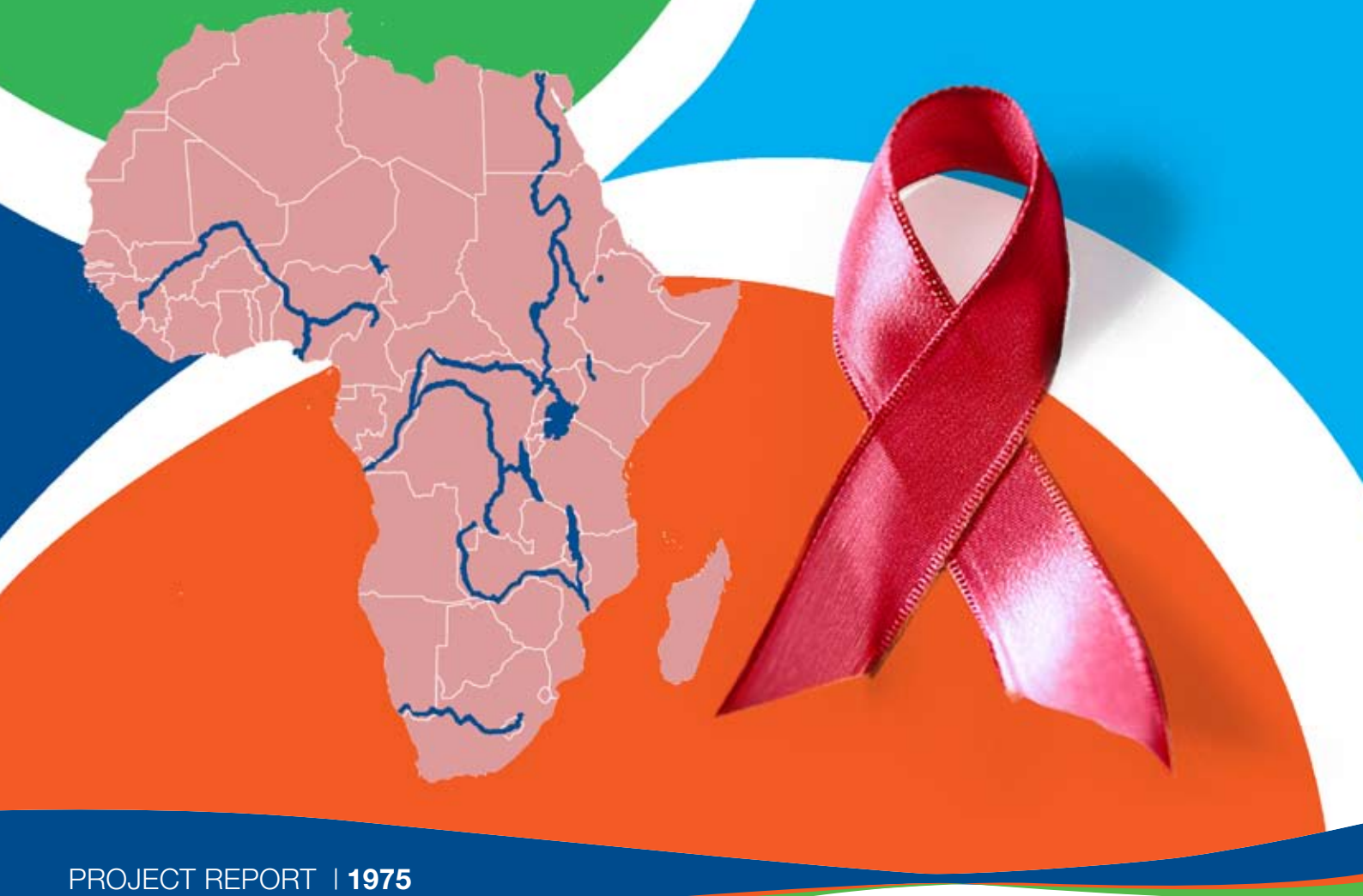

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Post-harvest handling of low-value fish products and threats to nutritional quality: a review of practices in the Lake Victoria region

Kabahenda, M. K. • Omony, P. • Hüsken, S.M.C.

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WorldFish CENTER

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Authors' affiliations:
M.K. Kabahenda (PhD): Department of Food Science and Technology, Makerere University, PO Box 7062, Kampala, Uganda.
P. Omony: Department of Fisheries Resources, PO Box 4, Entebbe, Uganda.
S.M.C. Hüsken: The WorldFish Center Zambia.

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1. Background

Under the Regional Programme *Fisheries and HIV/AIDS in Africa*[1], implemented by the WorldFish Center in collaboration with FAO, this paper is the second in a series of papers that have been generated from reviewing literature on trends in consumption and processing of low-value fish products marketed in the Lake Victoria region. The papers fall under the programme's research component in Uganda, analyzing nutritive quality and post-harvest activities in 'low value' fish market chains around Lake Victoria, focusing on Mukono District, Uganda.

The objective of this review is to examine the common practices in processing, preservation, and storage of low-value fish products marketed in the Lake Victoria region and the impact of these practices on nutritional quality of these products and their contribution to populations at risk for malnutrition and people living with HIV/AIDS (PLHIV).

2. Introduction

The boom of Nile perch in the early 1980s was coupled with ecological changes in Lake Victoria and the consequent declines in stocks of indigenous species of fish [1]. Local fisher folk in the Lake Victoria region did not like the taste of Nile perch and were not conversant on how to process and prepare it. Rabi (1996) reports on perch rotting on the shores of Lake Victoria as a result of local populations not knowing how to process and cook the large fatty fish. Following interventions that sensitized local communities and businesses on how to process and prepare Nile perch, this fish quickly became a commercial fish which was mostly filleted for export.

The processing, which mainly involved filleting for export market, was dominated by factories. Some artisanal processors are reported to have moved into squatter camps around the fish filleting factories and started earning their living by frying and selling the left-overs from fish filleting factories to the local communities (mostly fish heads and tails) [1]. Hence, the by-product processing business was born out of necessity by filleting factories discarding their waste and the need by artisanal processors to find raw material for their business. The current trend in utilization of by-products is not only a move to reduce waste but also a strategy to improve availability of nutrients and functional components to consumers who cannot access high-value fish [2].

As Elvevoll[2] points out, many nutrients and functional ingredients that are essential for good health are often lost in the process of extracting food components from fish waste and the degree of losses depends on the level of processing. Because of the nature of low-value fish products and processes used to improve the value of these products, there are potential

[1] Funded by the Swedish International Development Cooperation Agency (Sida) and the Norwegian Ministry of Foreign Affairs.

losses that are likely to have significant implications on dietary intake and nutritional status of the low-income groups who consume these products.

Fish is a very perishable commodity and hence susceptible to high post-harvest losses. Both physical[2] (or material) and quality[3] losses are high in fisheries sector [3] and these translate into losses in nutritional contribution of fish to the total diet and health of populations. A review of case studies on post harvest losses in several countries in Africa indicates high levels of losses both in quantity (material or physical losses) and quality (mostly due to downgrading) of fishery products [3]. According to this report, physical and quality post-harvest losses in *mukene* (*Rastreneobola Argentea*) fisheries alone are valued at 0 – 7.5% and 1.5 – 18.9% in Kenya, 20 – 40% and 20% in Tanzania, and 26 – 40% and 2 – 5% in Uganda, respectively [3]. These losses have major implications on the nutritional quality and availability of fish products to local populations.

3. Methodology

This paper is mainly based on a review of literature from peer reviewed journals. Databases used to access publications include HINARI, ScienceDirect, and Medline. Major websites visited include the United Nations Food and Agriculture Organization (FAO), HEDON, the Lake Victoria Fisheries Organisation (LVFO), Lake Victoria Portal, which is an information portal of the Socio-economics Research program of Kenya Marine Fisheries Research Institute (KMFRI), Uganda's National Fisheries Resources Research Institute (NaFFRI), the WorldFish Center, and through Google search engine. The search strings that generated much of the information provided here were 'fish processing and nutrient loss' and 'post harvest loss and fish'.

Generally there was no published literature on processing of low-value fish products. Information presented here is mostly about studies that have looked at whole fish or parts of fish - not necessarily low-value products. In addition, focus groups discussions and key informant interviews were conducted with artisanal fish processors at two landing sites in Uganda, to gain better insights into perceptions and processing of low-value fish products.

4. Low-value fish products and processing methods

The major factors that affect the nutritive value of fish products are related to how fish is handled, processed or preserved, and stored. Traditional practices such as exposing fish for long periods to weather elements coupled with traditional methods of preservation (hot smoking, sun-drying, and deep frying) and poor storage are subjecting fish to different kinds of degradation. Because of the high unsaturated fatty acid content of fish, free radical oxidation is a common phenomenon in all types of fish products (fresh or processed) that are

[2] Refers to discarded by-catches, fish that is discarded because it has spoilt due to lack of buyers, eaten by insects or eaten by birds/animals. Also includes pieces or exudates that are discarded during processing, gets burned during smoking, is not gathered properly from processing area, and from thefts.
[3] Fish that has undergone change (due to spoilage and fragmentation) and is sold at low price.

exposed to air [4]. Photosensitized oxidation is also a problem in sun-dried products while enzymatic oxidation is likely to be more pronounced in fish products that are partially processed [4]. In the sections that follow, the authors have looked at different processing methods and their effect on nutrient profiles and availability.

4.1. The nature of the product

Fish is regarded a healthier meat option due to the high content of Long Chain Polyunsaturated Fatty Acids (LCPUFAs), which are associated with improving health and preventing diseases of old age [5-9]. However, due to the high levels of LCPUFAs, fish products are susceptible to oxidation [4]. Oxidation of lipids is associated with a decrease in triacyglycerols and phosopholids and an increase in free fatty acids [10] and often results in a product with off flavors (rancid) which may not be appealing to many consumers. Fatty fish such as Nile perch have high levels of Polyunsaturated Fatty Acids (PUFAs), especially the □-3 fatty acids Eicosopentaenoic Acid (EPA) and Docohexanoic Acid (DHA), which are very susceptible to rancidity. The peculiar smell of Nile perch is mostly a result of rancidity and the intensity of its smell is related to the level of degradation. Fish is also a high protein product which makes it susceptible to rapid degradation by micro-organisms. Fish is thus a product that needs proper handling and processing in order to preserve nutrients and its functional components that promote good health.

4.2. Handling of low-value fish products

The major threat to the quality of low-value fish products is how the products are handled. Fish rejected from factories is one of the prime products in the low-value products market chain, however, this fish starts off already spoilt (second grade) or heavily bruised. For example, fish that is undersized is often rejected at landing sites and is often thrown around on the landing slabs during auction, hence making the fish susceptible to internal bleeding which aggravates rapid deterioration. Since there is no cold chain for fish meant for local consumption, fish rejected by filleting factories deteriorates very fast.

The by-products from filleting factories are even at greater risk of spoilage because these products are often treated as trash. By-products undergo tissue damage during processing, have a large surface area of flesh exposed to atmospheric air, and are stored at high temperatures, all of which are key factors that determine the rate and extent of rancidity [4]. Of the low-value fish products in Lake Victoria region, oxidation is likely to be pronounced in dark meats generated from trimming fillet and dark fibres in fish frames (gills, internal organs, and along the fin lines). Total lipid hydroperoxides has been found to almost quadruple in samples of dark muscle stored on ice for four days and bleeding fish seems to reduce the rate of peroxidation [11]. However, bleeding of fish is not practiced in the region partly because bleeding would be an added expense to the processors.

Furthermore, low-value fish products are not held under similar sanitary conditions as the fillet. Degradation is fastened by poor storage during transportation from the factory to the distribution points. Figure 1 below shows fish skeletons being sold fromthe back of a pick-up truck, which is a common practice in the Lake Victoria region. Different fish by-products are transported this way, without ice. Exposure to air and direct sunlight quickly renders fish

products rancid due to oxidation of lipids [10]. In addition, the metal surface easily gets hot and transfers even more heat to the fish products while the canvass that covers the fish traps in heat, further accelerating all kinds of oxidative and enzymatic reactions that lead to spoilage of the fish products.

Figure 1: Fish skeletons sold from the back of a pick-up truck

4.3. Methods used to preserve low-value fish products

In general, low-value fish products are processed in a similar manner as whole fish. Hot smoking, sun drying, and deep frying are the most commonly used methods for preserving low-value fish products in the region.

Hot Smoking

In Lake Victoria region, hot smoking is the most preferred method of fish preservation because smoked products attract good local and regional markets. Hot smoking is mostly used to preserve fish heads, steaks of rejected large fish, juvenile fish (tilapia, Nile perch, and catfish), and spoilt fish (second grade). Skeletons (frames) also used to be smoked but this practice is dying out because smoked frames are fragile and subject to fragmentation - which is a major reason for downgrading smoked products at regional markets. At one low-value fish processing site in Uganda, fish heads and rolls of fish skin were the two products that were being processed by hot smoking; these products were destined for regional markets.

Juvenile fish (mostly Nile perch) were smoked in the islands and smuggled onto the mainland where they attract high demand both at local and regional markets. Rejected mature fish was the only smoked low-value product processed at the landing sites and these rejects were being smoked alongside other high-value fish products.

Smoking is meant to preserve fish by reducing moisture content; however, the traditional smoking process is associated with unavoidable and large losses of nutrients. Before smoking, fish products are placed on racks in the kiln and allowed to drip dry for several hours, which results in some nutrients being lost in the exudate and the process also fosters microbial growth that induces proteolysis. During the smoking process, fat and more water drips from the fish resulting in physical loss of lipids (including essential fatty acids) and micronutrients. Hot smoking at high temperatures also degrades protein and reduces functionality of essential amino acids [12]. In addition, smoke particles are likely to react with nutrients in the fish and may lead to loss of important nutrients such as antioxidants. The totality of these losses often results in fish products with low nutritive value, thereby contributing to nutrition insecurity especially among those populations who rely on smoked fish products as their major source of animal protein.

Smoking is a preferred method of preservation because it dries the fish, melts down some fat, and reduces microbial growth [13]. When this is achieved, smoking is expected to extend the shelf life of most fish products to two weeks, but for only to four or five days for Nile perch products [14] and other fatty fish. With the growing fuel wood crisis [14, 15] fish products are not being smoked long enough to reduce moisture content to the recommended 10% or lower. This is mostly true for large perch steaks, heads, and skeletons that have not been scrapped of fats properly. Partially or unevenly smoked Nile perch products are susceptible to enzymatic lipid oxidation and protein hydrolysis, which results in losses of essential lipids, proteins, and other nutrients involved in these chemical reactions.

Traditional hot smoking involves stacking fish on wire meshes and then smoking it over open fires for one to three days [13, 14]. Artisanal processors on the Ugandan side of Lake Victoria indicated that, due to fuel shortages and high demand of smoked fish, fish products are often smoked for only one day. To reduce wastage due to inadequate smoking, measures have been taken to sensitize processors on the use of fuel efficient kilns and smoking methods that ensure an even drying of the fish [16]. Our research of smoking kilns in the islands and artisanal by-product processing sites on the Ugandan side of Lake Victoria revealed that many processors were using fuel efficient kilns but were not letting the fish to dry well enough.

The use of fuel efficient kilns has reduced fuel wastage but may be compromising the quality of smoked fish products. This mostly points to engagement of undesirable processing practices in effort to save fuel wood. For example, most processors (especially those on the mainland) were holding fish products on racks the whole day as they waited for more raw material to trickle in or as they prepared more fish products to fill the kiln. This practice exposes fish to flies and elements of weather which leads to deterioration before fish is smoked, and such smoked products spoil easily and hence contribute to both physical and quality losses. Another undesirable practice identified is the use of cow dung as fuel. Despite

the high risk for cross-contamination, cow dung was reported as the major fuel used for hot smoking fish on Lake Victoria's Businga island [17]. Besides the risk of cross-contamination, this practice compromises the quality of fish. Additionally, unrefined cow dung adulterates the flavor and taste of fish products and may lead to loss of returns on sale on these products as a result of downgrading. There are also reports of artisanal processors using fish guts to plug holes of smoking kilns [14], which attracts flies and other pests to kilns when the fires are out.

Sun drying

The drying process is a physical process where fish is exposed to air and direct sunlight. The time it takes to dry fish products depends on the nature of the product, the intensity of the sun, and the surfaces used for drying. The simplest form of drying involves exposing the fish to heat from the sun by placing products either directly on the ground, on mats placed on the ground or on racks [18]. Fish is typically sun dried for three to ten days [15] but drying periods of one to three days are more common.

Sun drying is the simplest and cheapest method of fish preservation; however, the drying process is know to affect protein quality the most [19]. During the drying process, the fish surface dries faster and hardens, thereby locking moisture inside, which slows the drying process and encourages degradation of protein and fatty acid oxidation. Degradation of protein is accelerated when fish products are subjected to high temperatures for an extended period [19]. Since traditional sun drying is weather dependant, some losses in quality also result from inadequate drying. For example, artisanal processors on the Ugandan side of Lake Victoria reported that they sun dry *mukene*, fish skeletons (frames), split heads, and chips for only one day to avoid loss in weight. This usually results in products that are susceptible to degradation.

In general, sun drying is mostly used to process small fish such as *mukene*. Sun-drying is also becoming a popular method for processing juvenile perch [20] especially for batches destined for markets in the Democratic Republic of Congo (DRC). It is estimated that about 5,000 tonnes of salted, sun-dried juvenile perch is annually exported from Uganda to the DRC through informal channels [20]. A large bulk of sun-dried fillet trimmings (locally called chips) from the Tanzanian side of the Lake is also exported to the DRC [21].

A case of sun-drying mukene at Kiyindi landing site

Traditionally, *mukene* is spread in the sun on the ground, on mats, or on old fishing nets. Such techniques are totally dependent upon the weather conditions. The ideal weather is dry with low humidity and clear skies. According to our interviews and focus group discussions with *mukene* processors at Kiyindi landing site (Uganda), during hot, dry and windy seasons, *mukene* dries within a day. During the rainy seasons, *mukene* does not dry in one day and sometimes the entire product is lost due to elements of weather and inadequate drying facilities. Since *mukene* is usually spread on the ground, processors are sometimes not able to gather their product on time, causing some *mukene* to be swept away or soaked by rain. The high humidity associated with the rainy seasons also precipitates rotting and growth of moulds especially when the product has not fully dried. These processes lead to degradation

of proteins, increased lipid oxidation, and loss of vitamins and thus reduce the nutritive value of *mukene*.

Artisanal processors at Kiyindi landing site and surrounding islands preferred drying *mukene* on the ground so as to fasten the drying processes. Many believed that it is the heat from the sand that dries *mukene* faster. Drying on the ground was also preferred because it results in sand sticking on fish and thereby increasing the weight of the dried product (which is an important attribute since *mukene* is sold by weight). Drying on racks was not a common practice in the study area but artisanal processors indicated that they had been sensitized on the use of racks. Racks were being used by only one foreign investor and his product was highly demanded for in the market at the landing site. The other artisanal processors advocated that government should put up drying facilities with racks because they cannot afford racks. Many of artisanal processors indicated that they migrate frequently and did not want to construct racks because they were not sure that they would live in the area long enough to benefit from such investments. This understandable attitudes should be taken into account when designing targeted interventions to improve the *mukene* drying process to ensure it increases its potential as viable livelihoods option for artisanal processors.

The other threat to the nutritive value of *mukene*, is the process in which it is stored. Dried *mukene*, including the partially dried product, is packed in gunny bags (also called poly bags) that lack aeration and hence renders the product susceptible to degradation. The problem is aggravated by the practice of stacking bags atop slabs of cement as shown in Figure 2 below. Bags at the bottom are subject to rotting from condensation from the slabs and the heat that accumulates inside the bags favors microbial activity and growth of moulds. Mukene stored under such conditions requires regular airing but this is often not possible because bags are heavy and stacked high which makes it hard to access bags that need airing.

Figure 2: Stacked gunny bags of dried *mukene* in storage stall (Kiyindi landing site)

Some storage areas also do not have adequate space for airing, as visible in Figure 3 below, and the product is often subject to losses from birds and weather elements. Degraded *mukene* and *mukene* dust is often diverted to fishmeal for animal feed but some rotten *mukene* sometimes ends up on local markets, where it becomes a potential health hazard for local populations.

Figure 3: Women airing *mukene* in storage area (Kiyindi landing site)

Salting and drying

Salting as a method of preserving fish has been used for centuries and in many places around the world such as Asia, Europe, and Latin America. Salting is popular because it is a simple method of preservation, is less costly, and easily performed together with other preservation methods such as drying or smoking. In the Lake Victoria region, salting and sun drying are commonly used to process all kinds of fish products including skeletons, heads, trimmings (chips), and juvenile Nile perch. In general, salted sun-dried fish products are not popular for consumption in the region, hence these products are sold to the DRC and Southern Sudan.

Salting preserves fish and significantly reduces microbial growth, however, salted sun-dried fish products are more prone to lipid oxidation than fish preserved by other methods because of exposure to light and oxygen [22]. Levels of free amino acids in salted sun-dried fish have been found to decrease during storage and the degree of amino acid loss was related to Millard browning [22]. Browning and the associated lipid oxidation and amino acid loss were possible at temperatures as low 25^{o}C (77^{o}F) in the presence of moisture [22] and these conditions are typical weather conditions for the Lake Victoria region. During the rainy season, high humidity leads to rapid deterioration of both salted and smoked fish products and it is estimated that as much as 50% of *mukene* harvested is likely to deteriorate during one single rainy season [16].

Deep Frying

Prior to the establishment of filleting factories, fat was extracted from gutting mature Nile perch and scrapping fat inside and around the guts and maws using hands or a knife. This fat was then melted to obtain oil for deep frying. Filleting techniques have improved accessibility of fish fat especially from the belly flaps and skins of perch and locally produced unrefined perch oil has become a valuable commodity in processing of different low-value fish products. In the Lake Victoria region, Nile perch oil is the major oil used to deep fry fish products such as whole fish, frames, skins, heads, eggs, and fish balls made from trimmings. Deep frying has the advantage of reducing fat, especially in Nile perch products which are naturally fatty. However, there is concern that deep frying may reduce the nutritive value of the oil and the fried products, especially since oil is subjected to high temperatures and is also reused many times.

In general, fish oils, because of their high content of unsaturated fatty acids, are highly susceptible to oxidative reactions which lead to rancidity. Rancidity can be easily detected by pronounced off-flavors that affect the overall quality of oils. Studies on fatty acid profile of oil from heads [23] and belly flaps [24] of Nile perch shows high levels of LPUFAs in Nile perch; notably, high levels of DHA and EPA, which are essential fatty acids important in human health and nutrition. Nile perch oil is also rich in vitamin A, β-carotene and α-tocopherol and is less prone to oxidation. It is not clear whether deep frying reduces both the levels of □-3 fatty acids, however, literature indicates that deep frying may have more effect on fatty acid functionality when compared to other direct heat treatment methods such as boiling and baking [8].

4.4. Threats to low-value fish products

Besides the effects of different processing methods described above, there are different other threats to low-value fish products, that have an impact on the quality and nutritional value of the products.

Fly larvae and beetles

House fly larvae (maggots) and beetles are the major pests that degrade smoked and dried fish products. Flies lay their eggs on fish at different levels along the market chain. The smell, especially from off-flavours resulting from microbial processes, attracts flies to the fish products. Other practices that increase exposure to flies are the absence of containers to keep fish covered during transport and storage. In addition, the nature of the fish products, especially the by-products, also induce flies to breed on fish. Flies try to protect their eggs by laying them in depressions such as incisions in the flesh of fish or in orifices such as gills and mouth, hence by-products such as heads and skeletons are ideal breeding ground for flies.

As can be seen from figure 4 below, the drip drying process of larger fish does not only result in physical losses of nutrients in exudates but also gives opportunity for flies to infest fish products. Fish dried on the ground also easily gets infected with fly larvae that stay in the soil

and move to the fish to feed, but return to the soil when fish gets very hot [18]. The practice of not drying fish products completely and unsanitary conditions also attract flies.

Figure 4: Drip drying fish prior to deep frying

Most insects that harbor in cured fish breed faster and increase in numbers around 25^{o}C to 35^{o}C and moisture content of 70-80% [25], so the high temperatures and humidity in the Lake Victoria region provide an ideal breeding environment for these insects. Insects and mites cause both physical and chemical losses to fish products. Both fly larvae and beetles feed on fish flesh and reduce its weight, which consequently results in losses in nutrients available for human consumption. It is estimated that that damage by flies results in losses of up to 30% of the weight of cured fish products during processing, while beetle damage results in about 50% losses during storage for several months [25, 26].

Microbial growth

Fish generally contains high protein and thus provides perfect media for microbial growth. Factors that are associated with microbial spoilage are method of catch, type of fish, sanitation, processing, and storage conditions. Handling of low-value products increases the risk for microbial spoilage. Microbial spoilage is estimated to cause physical losses accounting to about 10% of fish catches worldwide [27], hence impacts the availability of nutrients from fish products.

The impact of microbial growth on fish spoilage seems to be related to quality of fish products and types of micro-organisms involved. Most processing methods that dehydrate fish also reduce the rate of microbial spoilage. Hot smoking reduces microbial growth by reducing moisture content and by creating some phenolic compounds at the surface of fish products [13, 28]. This slows down the rate of degradation and the associated nutrient losses.

5. Conclusions and recommendations

This study shows that losses occur at different stages of the fish value chain. The three kinds of losses which were identified in this study are quality, physical and market force losses. The importance of a particular type of loss depends on the type of fish product and the stakeholder in question. Quality losses (such as bruising and rot) that result in downgrading of fish products are more important and significant to fresh fish traders whereas physical losses (mostly from rot and fragmentation) are experienced more by processors such as smoked fish handlers and *mukene* processors. Both physical and quality losses affect accessibility and dietary intake of key nutrients, notably: protein, fat and fat soluble vitamins, essential fatty acids, vitamin A, β-catorotene, and α-tocopherol. All these nutrients are important in nutrition, especially among populations whose diets are limited in these nutrients.

This review identified significant losses in nutrients as a result of oxidation of fatty acids and this oxidation is high in hot smoked and sun-dried fish. This is a major concern since smoking and sun-drying are the major methods of preserving fish products in the Lake Victoria region. There is need for more efficient processing methods that do not result in significant losses of key nutrients. This involves investigating and promoting simple technologies and desirable practices in fish preservation. For example, rancidity due to oxidation can be reduced by applying antioxidants and chelators directly on fish products and use of herbs as antioxidants has also been suggested. Artisanal processors at Kiyindi landing site, Uganda, advocated for improving access to solar dryers, which would offer an efficient and safe alternative.

The practice of partially drying fish products is becoming a common practice in the region and this practice needs to be discouraged since research and experience indicate that enzymatic oxidation is high in fish products which have not dried completely. Traders at Kiyindi landing site pointed out the lack of adequate drying grounds, the need to quickly get returns on investment, and the high demand for *mukene* as the major reasons for drying fish products only partially. All processors of sun-dried products, both on the islands and the mainland, felt that it was the government's responsibility to provide them with drying racks and alternative business so they can let their fish dry better. There is need to sensitize artisanal processors on how inadequate processing is having an impact on the nutritive value and loss of returns from sale of processed fish products, and their personal roles and responsibilities in this matter.

Improvements in sanitary conditions of handling and provision of alternative means of processing such as smoking, deep frying, and solar drying were singled out as possible options to enhance nutritional quality of *mukene* by artisanal processors at Kiyindi landing site. These processors advocated for overall improvement in drying facilities, construction of drying racks, and training of processors to reduce post harvest losses and therefore enhance nutritional quality of *mukene* products. Such strategies have shown improved processing of *mukene* (*omena*) in Kenya and led to improved returns. By-laws need to be introduced to discourage unsanitary fish handling practices such as drying on bear ground.

There is concern that improvement in quality of low-value fish products would lead to increased prices of these products and make them less accessible to populations at risk of malnutrition, especially PLHIV. This is mostly based on the fact that improved methods of processing and storage require cash investments. Strategies to improve the quality of low-value fish processing and storage should be coupled with efforts to control export of low-value products from the region and improved availability of these products to local populations that are at risk for malnutrition. This requires nutrition education at community level, on the benefits of consuming fish and the recommended ways of processing, storage and preparation. Additionally, beach management units and the Department of Fisheries Resources should be equipped with speedboat so that they can rigorously monitor undesirable practices and smuggling of low-value fish products.

One strategy for ensuring consumer access to safe and nutrient-dense fish products is improving access to fresh fish products. Most consumers in Uganda prefer fresh fish to treated products; however due to limited access to fresh fish, consumers who are not close to water bodies have developed preference to smoked and salted products. Improvements in the cold chain for low-value products can improve access of low-income populations to fresh fish since most low value products (especially factory by-products) are now generated from factories in urban centres. This will also improve the quality of raw material available for artisanal processors and improve the value-added products generated from left-over fish, which will consequently improve the livelihoods of artisanal fisher folk and fish processors in the Lake Victoria region.

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