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Evaluation of Fish Processing and Preservation Systems along the Shores of Lake Victoria towards Enhancement of Sun Drying Technology

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Abstract Fish products play an important role in human diet due to peculiar lipid composition. In Kenya Lake Victoria is an important source of fresh water fish contributing over 90% of the national fish production. The Lake Victoria fisheries support both the valuable artisanal and commercial fishery. This study aimed at identifying and documenting existing fish processing and preservation technologies practiced along Lake Victoria, Kenya and their adaptability in order to improve food security. Data documented in this study was gathered through open questionnaires, focus group discussions and stakeholders meetings. Demographically it reported that women accounted for over 85% of the fisherfolk of which over 70% had basic level of education. Technologically, sun-drying of fish is the most preferred fish processing method at the landing sites. However, over 97% of the sun-drying operations are done directly on the ground or on top of old fishing nets. The study observed that for new technologies to be utilized by the fisher's three important factors may play an important role in technology uptake by the fisherfolk, namely ease of technology to be utilized, the effectiveness of the technology and the cost of producing and maintenance of that new technology.

Keywords Fish Processing, Fish preservation, Fish products, Lake Victoria

1. Introduction

Fish from both natural sources and aquaculture are an important source of highly nutritive food, source of employment and of economic benefit. Fish products are important in human diet because of their digestibility and high nutritional value, mostly characterized by the presence of high quality proteins (contributes about 60% of the world's supply of protein while 60% of the developing countries derive 30% of their annual protein from fish [1], rich in amino-acids methionine and lysine. Fish and seafoods play an important role in human diet due also to their peculiar lipid composition, quite different from that of terrestrial animals. Fish lipids are rich in long chain polyunsaturated fatty acids belonging to the n-3 series, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), important constituents of cell membranes and essential in human brain and retina development. In humans, n-3 poly unsaturated fatty acids (PUFA) undergo metabolic reactions to form biologically active molecules known as eicosanoids (prostaglandins, thromboxanes and leukotrienes), that play vital roles in platelet aggregation, vasoconstriction and blood pressure regulation. Mineral elements like selenium, iodine (in marine species), phosphorus, calcium, sodium, potassium and magnesium and zinc are present in significant amounts in many fish species. Fatty fish store vitamins A and E in muscle tissue, while low-fat fish accumulate fat-soluble vitamins in the liver [2, 3]. In Kenya, Lake Victoria is an important source of fresh water fish and contributes over 90% of the national total fish production both for local and export markets. The lake is known to support valuable artisanal and commercial fishery [4, 5]. The major commercial fish species include exotic Nile perch (*Lates niloticus* L.), native cyprinid (*Rasneobola argentea* (Pellegrin), and introduced Nile tilapia (*Oreochromis niloticus* L.) [5, 6]. Lake Victoria is also a source of employment, food and income to riparian communities [4, 7]. Thus, fish remains the main source of protein and livelihood for the people living around Lake Victoria, Kenya.

Along Lake Victoria, fish is eaten freshly cooked, preserved and or processed, and therefore many technologies aimed at processing and or preserving the fish to avoid

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spoilages caused by pathogens do exist. Pathogens that are common inhabitants' of the natural aquatic environment may enter the final product via contamination routes such as; processing equipment and surfaces, food handlers and the water used in the processing plant [8]. However, these routes of contamination have not been adequately documented and in this regard, factors that influence the choice of the various preservation methods is not adequately understood. Thus, to consideration of these factors may open opportunities for improvement on the existing technologies or development of new ones. Generally, fish is prone to quality deterioration immediately after harvest resulting in economic losses. Fish spoilage occurs mainly as a result of bacterial metabolism of the fish muscle producing metabolites that decrease the quality of fish. The most common spoilage reaction is the production of biogenic amino of which trimethylamine is the most important [9, 10]. Studies have established that spoilt fish may have indigenous bacteria like *Clostridium botulinum*, *Vibrio* spp*., Aeromonas hydrophila* and enteric bacteria such as *Salmonella* spp, *Shigella* spp, *Escherichia coli*, as those which could cause food borne illness in human [11] as well and *Staphylococcus aureus*. For this reason, this study therefore set to identify existing processing and preservation technologies practiced along Lake Victoria, Kenya and their adaptability in order to improve food security.

2. Materials and Methods

The study was carried out within western Kenya (Lake Victoria Basin). This study sampled 45 sites comprising of 25 fish landing sites and 18 fish farming ponds/sites. Site selection was done randomly based on the percentage of fishermen per country as at 2004 where Busia had 8.1%, Siaya (29.7%), Kisumu (8.8%), Homa bay (41.6%) and Migori (11.4%); as well as fish production, Busia (9.5%), Siaya (18.6%), Kisumu (8.9%), Homa bay (51.7%), Migori (11.3%) [12].

Activities undertaken were carried out in two phases. Phase I involved holding stakeholders meetings, whereas phase II included field studies through holding focus group discussions (FDGs) and administering of open ended questionnaires. Stakeholders meeting were used to brainstorm and gather insights on the characteristics of the landing bays and fish ponds, existing fish species, fish processing and preservation methods, uptake of fisheries technologies and perception and causes of post- harvest losses. Participants for the stakeholder meeting were drawn from the government departments, private sector, NGOs and local communities engaged in fishing, transportation of fish, processing and preservation of fish and fish traders in western Kenya.

Focus group discussions were conducted to different categories of stakeholders at each study site to get more insights on the existing fish species, processing and preservation methods. The categories included fishermen, different fish processors, traders and transporters. Structured open ended questionnaires were then administered to at least 30 randomly selected; fish processors, traders and transporters to validate information from the FGDs on the existing fish processing and preservation methods. In-depth interviews were conducted to at least one identified key informant from each category of existing fish processing and preservation methods at each site.

Observations were made and photography taken of the existing fish processing and preservation methods at each site.

3. Results and Discussion

Table 1. Demographic data of the interviewed fisherfolk' in different fish landing beaches and ponds

	Frequency	Per cent (%)
Gender		
Male	16	14.8
Female	92	85.2
Marital status		
Married	86	79.6
Single	1	0.9
Widowed	20	18.5
Separated	1	0.9
Highest level of education		
None	9	8.3
Primary	74	68.5
Secondary	20	18.5
Tertiary	5	4.6
Residential status		
Local	58	53.7
Immigrant	49	46.3

Thousands of women have been working in the fishing industry throughout history and across nations. Their roles differ across fishing industries, communities, countries and regions. However, most women devote their efforts, talents and skills to the well-being of the family, engagement in the fishing industries. From the study it was found that there were more women involved in fish processing than men, representing 85.2% for women and 14.8% for men. Majority of the fish processors were married (79.6%) followed by Widows at 18.5% as shown in Table 1. Over 76% of the fish processors had formal education of up to 8 years of schooling. The findings further show that majority of the fish processor (≥53%) carry out fishing activities within the Districts of birth whereas 46% were immigrants. These findings demonstrate that along Lake Victoria fish value chain, fish processing is one of the important economic activities that engages women. Women are involved more on the lower levels of the fishery value chain having less access to resources and decision making. Thus the social- cultural values pertaining to religious concerns and attitudes make difference among the market places. In addition, women are still hindered from large-scale fishing (fishing-lots) and harvesting activities due to cultural benefits.

This study findings show that fish processors had very low levels of primary education which is attributed to high school drop-out resulting from early pregnancies, early marriages, low income in the families and attitude/perception towards education within the population. Women act as knowledge bearers of traditional fish processing and preservation techniques. Thus they play an important role in the transfer of knowledge from one generation to another. In the event that this is not practiced, then losses are envisaged in the fishing sector. In this regards, the findings of this study are close to those of LVFRP [13], who reported that 63% of fisherfolk as having primary level of education. This finding therefore demonstrates that in majority of the cases, persons with low education are most likely to join fishing as occupation. It is also possible that low education levels among the fisherfolk fork could be indicative of many people opting to drop out of school and venture in to fishing rather than stay in school as suggested by Luomba et al, [14]. Tiamiyu et al, [15] noted that levels of education affects the adaptabilities and receptiveness of technologies positively through effective skill acquisition in choosing better inputs. This has effects on the production line where efforts to develop new technologies should be linked to education standards of the users (fisherfolk) as well as developing policies to retain possible recruits in the fisheries industries.

There are relatively high level of immigrants (46%) in the study sites as show in Table 1. In Uganda, Kabahenda et al, [16] observed that many of artisanal fish processors being migrants do not want to invest in important infrastructure especially those that are aimed at improving fish quality such as construction of fish drying racks since they are not sure how long they would live in the fishing villages to benefit from the investments. Such attitudes should be taken into account when designing targeted interventions to improve the fishery infrastructure to ensure it increases its potential as viable livelihoods option for artisanal fisherfolk [16].

Table 2. Types of fish processed along Lake Victoria-Kenya

Type of fish	Frequency	(%) Percent
Tilapia	7	6.5
Nile perch	29	26.9
Dagaa	67	62
Others	5	4.6

Geographically communities around the world have adopted appropriate methods to suit fish harvesting, handling and storage based on their circumstances. Available fish species in their localities lead to development of unique methods for harvesting and processing for consumption. In this study *Rastrineobola argentea*, Dagaa/Omena (62%) is the most commonly processed fish along the beaches of Lake Victoria, Kenya as shown in Table 2. It is followed by the *Lates niloticus*, Nile perch at 26.9% followed by *Oreochromis niloticus*, Nile Tilapia (6.5%). This finding may imply that the types of fish targeted by fisherfolk for processing depend on their availability and the economic value. This is supported by the fact that data from the Ministry of Fisheries Department, has shown that Dagaa and Nile perch accounted for over 80% fish types that were landed within Lake Victoria Kenya. At the landing sites, freshly landed Dagaa was priced at about US$ 0.1/kg, Nile perch of low quality approximately US$ 0.4/kg, whereas tilapia was about US$ 1/kg. These price differences indicate that fisherfolk opt for the low cost products probably for them to make relatively higher profits as compared to tilapia fish. Nutritive value appeared not to be considered, as fisherfolk could opt for low quality fish products.

Table 3. Types of fish processing and preservation technologies employed along Lake Victoria, Kenya

Type of processing /preservation	Frequency/Counts	% Per cent
Icing	2	2.7
Deep frying	2	2.7
Sun-drying	57	78.1
Salting	2	2.7
Smoking	10	13.7
Sun-drying technologies		
Dried on the ground	7	6.5
On old fishing nets (placed on ground)	98	90.7
On racks	3	2.8
Quality of fish processed/preserved		
Freshly caught	76	70.4
Rejected fish (unauthorized size)	20	18.5
Spoilt fish (rejects)	1	0.9
Factors influencing choice of processing and preservation technique		
Cheap	51	
Easy to use	64	
Market preference	49	
Shelf life	59	
Nature of fish	30	

Application of fisheries technology starts from culture and ends at export of products. Post-harvest fisheries technology involves processing, preservation, handling, harvesting, marketing etc. Losses occur in all operations from harvesting through handling, storage, processing and marketing. In this regard, it was observed that sun-drying of fish as a technology was the most important fishing processing and preservation practice along Lake Victoria, Kenya. Three forms of sun-drying exist, namely drying fish on the ground, on old fishing nets placed directly on the ground and on racks and papyrus reed mats. Of the three technologies the most preferred is the drying of fish on old nets placed directly on the ground that accounted for over 90% of the practices. It generally appears that fisherfolk have compromised between using drying racks and drying fish directly onto the ground with the use of old nets. This is because unlike the use of drying racks, the use of old nets is cheap, easy to use and

produces fish products that has less contamination with soil and dust compared to those dried directly on the ground o based on sensory observation. Drying fish on the ground produces fish products of very low quality, not suitable for human consumption that is highly contaminated with soil, poorly dried and discoloured [17]. In all the cases observed in this study, Dagaa was dried on the ground if it was destined for the animal feed industry. All in all drying generally reduces weight, nutritive value and the digestibility of the flesh [18].

Further, sun-drying fishery products make them more prone to lipid oxidation because of exposure to light and oxygen [19]. Levels of free amino acids in sun-dried fish decrease during storage and the degree of amino acid loss was related to browning [19]. Browning and the associated lipid oxidation and amino acid loss are possible at temperatures as low as 25°C in the presence of moisture according to Smith and Hole, [19]. During the rainy season, high humidity leads to rapid deterioration of processed fish products (sundried and smoked). It has been estimated that as much as 50% of dagaa harvested is likely to deteriorate during one single rainy season [20].

The findings also show that most of the fish processed at the landing sites are freshly caught fish. Generally freshly caught fish should give high quality end products. However, the processing techniques employed by the fisherfolk lead to production of low quality end products [16] as previously explained. Processing of fish of unauthorized size (undersized fish) accounted for 18.5%, which form a significant amount. This could serve to demonstrate occurrence of illegal fishing practices according to the local Fisheries Regulations which according to Mbuga et al [21], small scale traders act as providers for a ready market for fish products harvested using non-selective fishing gear.

Smoking is also an important processing technology of fish products along Lake Victoria, Kenya accounting for 13.7% as shown in Table 3. Smoking however accelerates rancidity of fat, reduces digestibility of fat products and aexffect on protein quality [22]. Smoking procedure reduce the content of FDNB-reactive lysine. During smoking carbonyls are generated and react with lysine thereby reducing protein quality [23]. Fisherfolk along the Lake use traditional kilns for the smoking operations. These smoking kilns have no thermo regulation devices and therefore expose the fish products to excessive or limited smoking and heat. Procedures in which the fish is heated to fairly high temperatures such as smoking can result in changes in the nutritional value of fish protein, with losses in availability of lysine and other essential amino acids. According to Carpenter and Both [24], fairly high temperatures of about 150°Care encountered in smoking especially in Africa where hot smoking is preferred affect the availability of lysine, one of the amino acids found in fish proteins, methionine and other sulphur amino acids and vitamin K. The outcomes of this processing method are losses due to over-cooking of the product and therefore the products are burnt giving them poor appearance full of carbon suit surface covering, easy breaking of the fish due to them being fragile. Secondly the nutritional quality of the product is lost as well as appeal to the eye [16]. Limited smoking may lead to the products not drying adequately may lead to deterioration in quality during storage or when offered for sale in markets as confirmed by the presence of fungal growth in some of the marketed fish products. Some artisanal processors along Lake Victoria (Uganda) indicated that, due to fuel shortages (i.e. lack of adequate fire wood) and high demand of smoked fish, fish products are often smoked for only one day which is inadequate to dry fish effectively [16]. A typical fish processing oven (kiln) along Lake Victoria (Kenya) where fish smoking is done is shown in Fig. 1.

Figure 1. A picture of a traditional smoking kiln (Chorkor oven)

The perishable nature of the products and lack of storage facilities were identified as factors contributing to such fish products being offered at cheap prices. The price of 25 kg of Dagaa was about US$2.5, whereas 1 kg of good quality Nile perch was about US$2 and that of low quality US$ 0.4 at the time this study was conducted. It is this low quality Nile perch that was targeted for processing and preservation (sun-drying and smoking) at the fish landing sites. With such low quality products processed, the end products will be of low nutritional value, as nutrients are lost during spoilage.

The study also observed that the processors preferred some technologies because of ease of use such as sun-drying, smoking of fish in chorkor oven (Fig. 1). Although the quality of end products was not determined, overall quality of the products were low especially products processed by sun-drying by placing fish directly on the ground (Fig. 2) based on physical appearance and levels of contamination with sand and dust [25, 26]. Other important factors influencing adoption of technologies adoption along Lake Victoria, Kenya included the cost of the technology and the shelf-life of the fish products produced by such technologies. These three factors recorded over 50 responses as shown in Table 3. This cound be the reason why racks (Fig. 3) and other improved technologies may be less preferred by fisherfolk and therefore their low uptake. However these improved technologies give better shelf-life, than the traditional ones, but it is hypothesized that the fisherfolk consider the opportunity cost of improved prolonged shelf-life to initial input cost of improved technologies as insignificant.

Figure 2. Sun drying of Dagaa (*R. argentea*) on old fishing nets placed on the ground

Figure 3. Sun drying of Dagaa on raised racks

Figure 4. Fisherfolk collecting Dagaa after drying and packing them in gunny bags for transport to the market or storage

Table 4. Methods of packaging and storage of fish products

Item	Frequency	% Percent
Frequency of storage of fish products		
Always	35	32.4
Sometimes	58	53.7
Rarely	9	8.3
Never	4	3.7
Types of fish stored		
Sundried Dagaa (omena)	61	56.5
Smoked fish (kiln processed)	27	25
Other smoked fish	1	0.9
Deep fried Daagaa (Omena)	1	0.9
Deep fried Nile perch	6	5.6
Iced Nile perch/tilapia	2	1.9
Location of storage facility		
Designated area	4	3.7
Leased rooms	22	20.4
Within house hold	73	67.6
Use private store	7	6.5
Storage facilities ownership		
Self	78	72.2
Landlord	28	25.9
BMU	2	1.9
Challenges encountered at the storage facilities		
Lack of security (lose of fish products)	26	24.1
Inadequate space	10	9.3
Melting of ice	1	0.9
Accidents (attack by pests etc)	2	1.9
Rain	1	0.9
Loss of weight	12	11
Packaging of fishery products		
Gunny bags	87	80.6
Papayrus baskets	19	17.6
Paper	2	1.8
Does the packaging protect the fish products		
Yes	27	25
No	68	63
Not sure	13	12
Factors that influence choice of packaging material		
Quality of fish	60	55.6
Nature of fish products	35	32.4
Distance market	39	36.1
Market characteristics	23	21.3
Tradition	28	25.9
Suitability	41	38
Availability	42	38.9
Ventilation	37	34.3

From the findings of our study fish product are less frequently stored at the landing sites. Over 60% of the respondents never store or only occasionally store their processed fish products. Sundried Dagaa (56.5%) is the most frequently stored fish product followed by smoked fish products at 25% (Table 4). There are two possible reasons for this; first, the fish processors may not wish to store their processed fishery products due to their low quality and poor handling practices observed during processing operations at the landing sites so as to avoid immediate quality deterioration before getting to the market. Secondly the high demand of the processed fish products and the urge for quick sale in the market could make storage to be unnecessary. In addition, where stores were available, they were poorly ventilated leaving the ambient temperatures to prevail further

exposing the fish product to high moisture content and insect attack, increasing contamination with microbes and post-harvest losses [27]. Moshood et al, [28], noted that most of the isolated bacterial organisms from the fish products recovered in their study were probably introduced after the smoking operation is over an indication of post-smoking handling hygiene of fish.

Most of the stores along Lake Victoria, Kenya are privately owned with less than 1% belongs to Beach Management Units (BMUs). The findings show that over 65% of respondent processors stored fish products within their homes. The most important challenges the processors face during storage of fish products included lack of security; as products are either attacked by vermin or products could be stolen. Other challenges include inadequate storage space and loss of weight of products during storage which may make the fisherfolk to incur further economic losses.

Table 5. Uptake of solar technology

Item	Frequency	% Percent
Fisherfolk who have heard of solar driers		
Yes	60	55.6
No	48	44.4
Factors that could influence uptake of solar drier technology among the fisherfolk		
Operational costs	41	38
Its efficiency	82	75.9
Improves product quality	44	40.7
Its sustainability	36	33.3
Affordability	50	46.3
Durability	31	28.7
Impact on the environment	32	29.6
Training on new technology	43	39.8

After processing the fish products are packaged ready for market or storage. The most commonly used packaging material is the gunny bag, accounting for 80.6% followed by baskets made of papyrus reeds accounting for 17.6%. Other material but not very significantly used was paper that included newspaper, polythene, and cartons. In this study gunny bags are the most commonly used packaging material. According to Njai, packaging material should possess important characteristics, such as adequate strength to protect the packaged product from damage, be readily available and easy to use, including be clean to prevent contamination by undesirable substances. Majority of the fisherfolk (63%) think that the packaging material used do not protect the fish product, only 25% agreed that they do protect the product. However, over 55% of the fisherfolk make the choice on the type of packaging material to use on the fish products due to its effect on the quality of fish. Suitability of the material to be used as a package, availability and strength of the material to withstand transport vigor are also important factors recording responses of above 36%. Generally these are important factors which agree with those proposed by Njai for consideration while choosing a packaging material. Although the fisherfolk are aware of the importance of these factors, they however, do not use packaging material that complies. For instance using polythene gunny bags (Fig. 4) or bucket lined with polythene does not allow proper ventilation of the products, hence renders the product susceptible to degradation [16].

Over 55% of participants interviewed in this study have heard about fish solar driers as shown in Table 5. However over 75% suggested that they would only adopt the solar drier technology if the technology is efficient in drying fish. Other factors driers include product quality improvement; and affordability, which recorded over 40% responses.

4. Conclusions

Based on our findings, since over 70% of the fisherfolk have basic level of education, simple and les complex fish processing technologies should be offered to them. Women account for over 85% along Lake Victoria, Kenya, and generally play numerous roles in the fishery which may also influence uptake of any new technology offered. However, for the technologies to be utilized by the fisherfolk three important factors were identified to influence uptake; these include ease of technology to be utilized, its effectiveness for instance if it prolongs shelf-life of the product and have low cost of production and maintenance.

Dagaa (omena) and Nile perch are the two major fish types processed within Lake Victoria, Kenya and that sun-drying is the most commonly used technology. Although direct drying on the ground or on top of old fishing nets accounts for over 97%, the technologies do not guarantee the safety of the product and are also less effective as they are contaminated with soil and dust and therefore responsible for high levels of post harvest losses due to quality deterioration. Therefore a technology that aims to change this scenario may have a high impact on fish post harvest loss along Lake Victoria, Kenya but should also be easy to use and affordable to the fisherfolk.

The study also shows that the fisherfolk along the shores of Lake Victoria in most cases make their own fish storage arrangements. Although there are Beach Management Units (BMUs) present in all the fish landing sites. Over 80% of the fisherfolk require storage facilities demonstrating a need for such facilities. Having designated storage facilities may also improve the quality and safety of the fish products, by offering pest control and minimizing contamination. Storage facilities at the landing sites are mainly required for sun-dried dagaa and smoked fish products.

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