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ORIGINAL PAPER

Post-harvest interventions in small-scale fisheries: a boon or bane to food and nutritional security in Kenya?

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Abstract

Small-scale fisheries in Kenya contribute about 4.7% of the Gross Domestic Product (GDP) in spite of high post-harvest losses. Post-harvest interventions in fisheries enable fishers and fish processors to reduce waste, maintain nutritional aspects and meet stringent demands in food quality and safety. This review highlights the benefits and pitfalls of various fish post-harvest management interventions in order to drive policy dialogue and formulation of a regulatory framework for future interventions. It relies on data obtained from the Kenya Marine and Fisheries Research Institute and the State Department of Fisheries and Blue Economy. Results depict abundant interventions in both handling and processing, but low utilization (<40% of installed cold rooms, dryers and smoking kilns) and multiplication by fishing communities. Fish products that target export markets have well-organized structures. However, a weak regulatory framework is a key constraint in addressing post-harvest management of fish intended for the domestic market. Under-utilization of installed interventions results in continued waste of fish, contributing to food and nutritional insecurity. This review recommends the development of an effective and integrative policy framework that involves interactions across different domains, institutional mechanisms that monitor and address those interactions, analytical bases for decision making, and multi-stakeholder dialogue for post-harvest management. Such policies will enhance the adoption of post-harvest technology in small-scale fisheries in Kenya and elsewhere.

Keywords Post-harvest · Interventions · Small-scale · Fisheries · Food · Nutrition

1 Introduction

Globally, capture fisheries and aquaculture produced 167.2 million metric t of fish in 2014 (Bennett et al. 2018), translating to 17% of the animal protein consumed and 20 kg consumption per capita annually (Adrien 2015; Bennett et al. 2018). Within capture fisheries (approximately half of the total global production), nearly half of production is from small-scale fisheries (artisanal fisheries), employing on average 90% of the world's fishers, almost all of whom live in developing countries (FAO 2018). These figures may be an underestimation of the contribution of small-scale fisheries to food security, given that subsistence fishing (e.g., fishing for own consumption) as well as informal trade is often underreported in official statistics (IOC 2012).

In Kenya, fisheries contribute nearly 4.7% of the GDP and about 2% (approx. US$ 60 million) of the national export earnings (KNBS 2015; LVFO 2015; Fisheries Bulletin 2016). The sector employs in excess of 65,000 fishers directly and an estimated 1.2 million people indirectly (Fisheries Bulletin 2016). The notion of a "Blue Economy" is gaining impetus in most developing countries and could augment the contribution of their fisheries sectors to food and nutritional security. In the present review, we define fisheries production based on water body as either Marine or Freshwater/inland (Fig. 1), as well as the fishing operation as either small-scale or industrial. The Kenyan fishery is mainly small-scale with very few commercial/industrial vessels targeting mainly shallow water shrimps, deep water shrimps and lobsters (Fisheries

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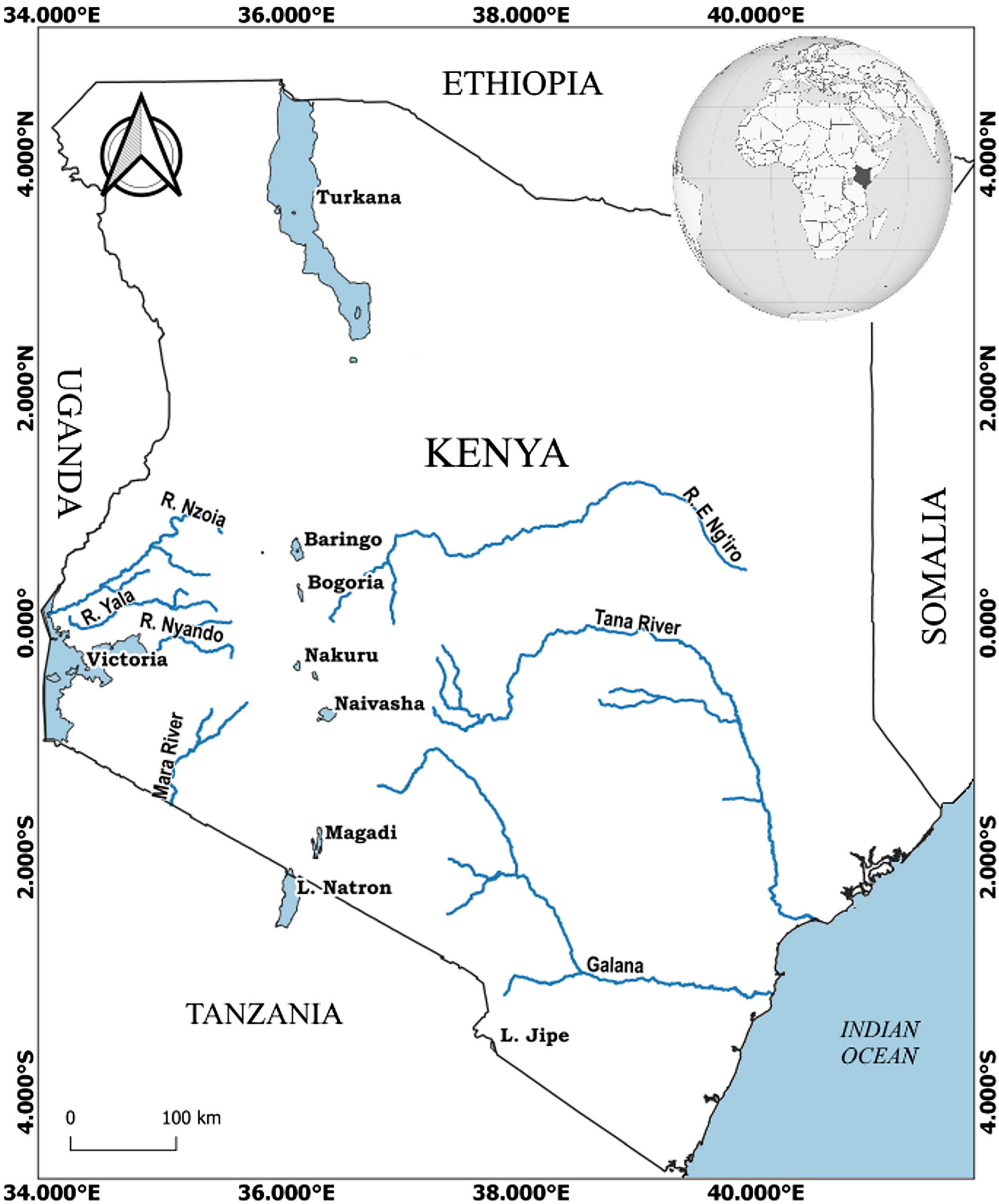


Fig. 1 Map showing marine and inland water bodies of Kenya

Bulletin 2016). In recent years, Kenyan flagged long-liner and purse seines vessels owned by Distant Water Fishing Nations have been exploiting Kenya's Economic Exclusive Zone (EEZ) (FAO 2016; Adrien 2015; Fisheries Bulletin 2016).

Small-scale fishery accounts for most of the inland and marine water landings reported in this review and is the most important type of fishery in Kenya. Inland (freshwater capture and aquaculture) fisheries that are small-scale, accounted for 83% of the 147,726 t of fish produced in Kenya in 2016 (Fisheries Bulletin 2016). Lake Victoria - Kenya (6% of the whole lake = 4,128 km^2) accounted for about 66% of the total fish produced (Table 1). Besides Lake Victoria, other freshwater capture fish sources include lakes Turkana (6,405 km^2), Naivasha (210 km^2), Baringo (129 km^2) and Jipe (39 km^2), several dams and rivers spread throughout the country (Fig. 1), collectively producing nearly 7% of total fish production (Fisheries Bulletin 2016).

Marine fisheries are centered in the Western Indian Ocean (WIO) with a coastline of 640 km, consisting of 12 nautical miles of territorial waters (9,700 Km^2) and an EEZ extending to 200 nautical miles with a total area of 142,400 km^2 (Fig. 1) (State Department of Fisheries 2016). The marine fisheries support a wide variety of fish species including fin fish, both pelagic and demersal, as well as crustaceans and molluscs (Manyala 2011). It is estimated to have an annual potential of 150,000–300,000 t (KMFRI, unpublished data) but the existing production level was reported in 2016 to be 24,709 t, constituting about 17% of total production (Table 1). The Kenyan aquaculture sector is broadly considered either freshwater aquaculture or mariculture. Whereas freshwater aquaculture has recorded substantial growth over the last decade, the mariculture sector is yet to be fully exploited (Nyonje et al. 2011; Munguti et al. 2014). Cage culture, that seems to be a promising venture towards greater national fish production (Aura et al. 2017), is growing rapidly in Lake Victoria. The lake has over 3,000 cages, holding more than 3 million tilapias valued at US$ 12 million (Njiru et al. 2018).

Furthermore, the Kenyan fishery is characterized by diversified value chains: fresh and processed fish, industrial and artisanal processing, domestic and export markets, food and feed products (IOC 2012). However, it is predominantly small-scale wherein post-harvest losses (physical and quality) occur (Ofulla et al. 2011; Cyprian et al. 2013; Odoli et al. 2013). A study in some sub-Saharan countries (Ghana, Kenya, Mali, Tanzania and Uganda) show substantial post-harvest losses in small-scale fisheries occur at all stages during fish distribution and utilization (in the value chain); from capture to consumption (Oduor-Odote et al. 2014; Kolding et al. 2016). Post-harvest losses can be defined as nutrient or economic losses that render the fish unavailable or nutritionally deficient for human use (Tesfay and Teferi 2017). The losses pose an impediment to the contribution of small-scale fisheries to the sustainable development goals (SDGs) of hunger eradication (food security), health improvement (nutrition), and women's empowerment (since many women are gainfully employed in the fish trade). This is especially important in small-scale fisheries of developing nations where post-harvest losses are substantial (Cyprian et al. 2008; Rawdkuen et al. 2010; Adrien 2015).

It is predicted that in future, per capita fish consumption will increase on all continents, except Africa where the human population is expected to grow faster than fish supply (IOC 2012). This makes the efficient utilization of fish as a food resource and the reduction of losses along the value chain highly important in Africa. Ideally, the most palpable approach of increasing fish supply without raising the fishing pressure/landing is by reducing post-harvest losses of what is currently produced. In an attempt to promote sustainable small-scale fisheries in the context of food security and poverty eradication in Kenya, numerous post-harvest management interventions have been made by government, development partners and stakeholders (Adrien 2015). Similar initiatives are seen globally where several countries and regional organizations have developed relevant policies and strategies (Marsden et al. 2018), as new initiatives in addressing issues with small-scale fisheries more explicitly (FAO 2018). Nonetheless, high post-harvest losses are still reported against the sector's framework in post-harvest management (innovations) aimed at reducing losses and in boosting food security and poverty eradication.

According to the Schut et al. (2015) 'Agricultural Innovation Systems (AIS) approach', innovation is perceived as a process of combined technological (e.g. in fisheries: cold chain infrastructure, processing equipment) and non-technological (e.g., social practices) changes. The changes occur across different levels (e.g. in fisheries: in a sea/lake, at a landing site, region), and are shaped by interactions between stakeholders and organisations inside and outside the sector. This emphasizes the need for better understanding of the drivers of post-harvest innovation and identification of entry points for the innovation to overcome reported losses. If post-harvest losses occurring in small-scale fisheries are reduced through the adoption of innovations, there is potential to increase supply and retain the nutritious value of fish and fish products. This will contribute towards eradication of food insecurity, malnutrition and poverty, as well as the sustainable use of small-scale fisheries resources, and the achievement of SDGs 1, 2 and 14 (FAO 2018).

This review helps to highlight benefits and lessons from various post-harvest management innovations in small-scale fisheries to provide a regulatory framework that can guide related policy dialogues among development practitioners as a support tool for future interventions in the subsector. Our paper used prevailing literature, frame survey data and information from the Kenya Marine and Fisheries Research Institute (KMFRI) and the Kenya State Department of Fisheries and Blue Economy (SDF and BE). We review the contribution of post-harvest management interventions in small-scale fisheries (along the value chain) to nutrition and food security in Kenya.

2 Small-scale fisheries, nutrition and food security

Globally the consumption of fish as food has doubled since 1973 and the developing world is responsible for over 90% of this growth (FAO 2018). Much of the growth is from small-scale fisheries, especially aquaculture, but also fresh water capture fisheries (FAO 2011; FAO 2018). Fifty percent of all food-fish originates from small-scale fisheries, and almost all fish from small-scale fisheries is used for food (Béné et al. 2016). In contrast, a substantial percentage of the catch from industrial fisheries tends to be used for animal feed and other products and not for direct human consumption (FAO 2011; Béné et al. 2016). This shows the important contribution of small-scale fisheries for food security, which can be summarized under five headings: direct contributions to household food security; indirect contributions to household food security; direct contributions to domestic markets (local and national levels); indirect contributions to domestic markets (local and national levels); and contributions to international (worldwide) food security (Table 2).

Food security is a condition in which people have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 2011). There are four measures of food security: availability, access, stability and utilization (Izraelov and Silber 2019). These measures, and in particular 'utilization', symbolize the food and care related aspects of good nutrition (Bennett et al. 2018). There is a growing literature documenting the contribution of fish to nutrition and food security (e.g., IOC SmartFish 2012; Béné et al. 2016; Ogello and Munguti 2016; Izraelov and Silber 2019). This is because fish and fishery products represent a valuable source of nutrients for diversified and healthy diets since they provide high-value protein, a wide range of essential micronutrients (vitamins D, A and B, several minerals (i.e. calcium, phosphorus, iodine, zinc, iron and selenium)) and polyunsaturated omega-3 fatty acids (Cyprian et al. 2017). There is well-established proof that fish consumption has protective effects on a wide range of health issues, including incidence of stroke (Béné et al. 2016), high blood pressure and coronary heart disease (Ogello and Munguti 2016), but the mechanisms through which these diverse effects occur are poorly understood. A study conducted in Tanzania reported the breast milk of women who consumed high levels of freshwater fish had DHA (an important omega-3 fatty acid) levels higher than those recommended for baby formulas (Bennett et al. 2018).

Nutrient profiles vary across fish species, processing or preparation techniques, and habitat (Bennett et al. 2018). Investigations in East Africa reveal fish to be an important animal product in the region's diet, due to its availability and affordability (Oduor-Odote et al. 2010a, b; IOC 2012; Mbwana et al. 2016). The actual contribution of fisheries to nutrition and food security depends on the supply, distribution, and utilization of fish. Nonetheless, knowledge about the contributions of fisheries to nutrition and food security is

Table 1 Fish landings by weight (metric tonne) and value (US$) from various water bodies (freshwater and marine) in Kenya between 2014 and 2016

Fresh water	2014		2015		2016	
	M t	US$	M t	US$	M t	US$
L. Victoria	128,708	146,017,900	109,902	144,948,390	98,166	146,025,680
L. Turkana	4,166	4,337,900	10,605	7,357,170	7,926	5,764,930
L. Naivasha	633	6,80,700	1,072	1,326,170	1,064	1,410,060
L. Baringo	302	865,950	176	548,590	141	415,950
L. Jipe/Dams	115	192,490	122	210,310	106	187,190
L. Kanyaboli*	134	104,660	100	98,740	94	98,700
L. Kenyatta*	51	38,990	64	50,850	48	45,600
Tana River Dams	1,024	983,110	852	1,150,200	444	722,290
Turkwel dam	56	115,470	28	59,360	42	90,300
Tana delta	47	35,740	54	48,180	20	19,700
Riverine	8	18,940	24	42,120	14	35,000
Aquaculture**	24,096	56,017,220	18,656	50,141,490	14,952	42,538,440
Freshwater Total	159,340	209,409,070	141,655	205,981,570	123,017	197,353,840
Marine						
Marine Artisanal	23,287	46,413,490	22,407	37,955,750	24,165	44,341,260
Marine Industrial	83	252,050	248	695,990	544	1,779,470
Marine Total	23,370	46,665,540	22,655	38,651,740	24,709	46,120,730
Grand total	182,710	256,074,610	164,310	244,633,310	147,726	243,474,570

*Oxbow lakes; ** Fish farming; L = lake (Source: Fisheries Bulletin 2014–2016)

Table 2 Dimensions of food security (modified from FAO 2007)

Level	Direct contribution	Indirect contribution
Individual/household level (micro)	Through subsistence (Assumes the ability of the household to utilize the commodity).	Through self-employment or wages.
Domestic level (meso, macro)	Direct food self-sufficiency through effective commercialization or redistribution of national surplus.	Indirect food self-sufficiency through foreign exchange earnings (food import).
Global	Limited nature of capture fisheries. Highlights the role that aquaculture and improved fisheries management and utilization will have to play in the future to ensure global fish food security.	

mostly focused on supply (aquaculture and capture fisheries) (Béné et al. 2016; Ogello and Munguti 2016). The explicit links between fish distribution and utilization (where post-harvest losses occur) to nutrition and food security need to be amplified.

Fish consumption does have some risk of exposure to toxic substances, such as polychlorinated biphenyls, dioxins, methyl-mercury and lately, increasingly with micro-plastics (Bennett et al. 2018). These risks undermine the contribution of fisheries to nutrition and food security, even though they vary dramatically based on the type of fish consumed and the environment in which fish is caught. But, the general consensus is that the benefits associated with fish consumption outweigh the risks, even at high consumption levels for the general population (FAO 2011).

3 Fish handling in small-scale fishery and food security

Fish are fragile and deterioration of the quality starts immediately after they are caught. The deteriorative changes are due to chemical, enzymatic and bacteriological activities which are accelerated or retarded by physical conditions such as temperature, damage to fish, pollution and contamination by bacterial flora (Magnússon et al. 2006; Cyprian et al. 2008; Van Nguyen et al. 2012). The storage life of fish under ambient tropical conditions is less than a day (Odoli et al. 2013) depending on handling conditions, species, quality of fishing ground, season, sexual and nutrition status (Huss 1995). Unlike in a commercial (industrialized) fishery where precautionary measures are taken to freeze the catch or maintain low temperature, in small-scale fisheries of most developing nations, fish is poorly handled (Odoli et al. 2013; FAO 2016). Small-scale fishermen or fish farmers in Kenya for instance, lack ice facilities during fishing and fish harvesting, yet they spend considerable time (6 to 12 h) between catching and landing or selling the harvested fish (Ofulla et al. 2011; Odoli et al. 2013; Oduor-Odote et al. 2014). This restricts the sale and consumption of fish to nearby fishing communities thus deterring its availability and accessibility to communities living further away.

'Upstream' fish handling in most small-scale fisheries involves placing the catch on woven mats or in gunny bags at the bottom of the vessel (either bare or lined with gunny bags) or on raised holding units in the prow of the vessel, and the fish covered with bags/nets (Odoli et al. 2013; Odoli et al. 2017). The outstanding technological aspects in this conventional handling of fish include the drip way enabled by the porous nature of handling apparatus; the sheltered location of the storage place that shades caught fish; and occasionally, the raised storage that prevents soaking of a catch in seeping boats. Nevertheless, these methods expose fish to a risk of contamination from the handling apparatus in contact with the fish, such as vessel bottoms and baskets or bags. This, in addition to exposure to air and high ambient temperatures during fishing and transportation, accelerates fish deterioration.

Handling practices in small-scale fisheries are partly determined by the quantity of fish caught, as carrying baskets and bags have limited holding capacity (Odoli et al. 2013). These practices are in contrast to the obligatory fresh fish handling standards (Codex Alimentarius Commission 2016), where measures need to be taken to maintain the quality and nutritional attributes (Martinsdóttir et al. 2001). Although the landed fish is acceptable for human consumption, the long time lapse and unsanitary handling prior to landing or selling denies bargaining power to fishers and access to better markets further away.

Fish post-harvest interventions should maintain the quality, the value and acceptability of the final product. However, post-harvest handling depends on the available infrastructure and technology, fish type, as well as the market preference (Gram and Dalgaard 2002; Cyprian et al. 2017). Upon landing, the Kenyan fish market has a structure that categorizes traders as either focusing on the domestic market or dealing with the international market (IOC 2012). Though fish cold-chain infrastructure is poorly developed, and where developed is generally ill-used, the species targeting international markets such as Nile perch, octopus and prawns have a well-organized system with provision of ice and refrigerated trucks along the value chain to meet the required handling standards (Manyala 2011; GoK 2016). But handling of fish intended for domestic markets does not adhere to the established sanitary and phytosanitary standards in the country (Tanui, pers. comm.). This occurs despite there being many post-harvest management interventions that could be used to avoid post-harvest losses. The need for cold chain infrastructure on board fishing vessels as well as at landing sites to maintain quality and nutritional attributes of fish and fish products cannot be overstated. Cold chain infrastructure will allow wide distribution and marketing of fish in both domestic and international markets while offering fishers bargaining power for their catch, improving their livelihoods and, as a result, contribute to nutrition and food security, as well as poverty eradication.

4 Post-harvest management interventions and food security

4.1 Prerequisite for post-harvest interventions

Development in the marketing and consumption of fish and fishery products in recent decades has been accompanied by growing interest in food quality and safety, nutritional aspects and waste reduction (FAO 2018). This has led to the adoption of stringent hygiene measures at both national and international levels in the interests of food safety and consumer protection (Codex Alimentarius Commission 2016). The Codex delivers guidance on useful aspects of applying good hygienic practices and the HACCP food safety management system. In East Africa, member countries are also changing policies for trade in fish and fishery products across borders (IOC 2012), necessitating the need for interventions along the value chain to ensure product quality and safety. This, among other factors such as reducing losses, have led to considerable investment in fish post-harvest management by governments, donors and other stakeholders in the small-scale fisheries subsector.

4.2 Post-harvest interventions in handling

Fish landed in East Africa is marketed as fresh whole fish or in filleted, sundried, smoked and fried forms. Small-scale fish handling from catch to fork can expose fish and fishery products to contamination (Odoli et al. 2013). In Kenya for instance, government and a series of development partners (the European Union, Kenya coast development project (KCDP) and Lake Victoria environment management project (LVEMP)) installed some basic fish post-harvest management infrastructure at landing sites. They included cold rooms, ice making machines, pontoons/jetties, potable water, electricity supply, fish stores, drying racks, smoking kilns, access roads and toilet facilities (Table 3). The proportion of fish landing sites in 2016 with all-weather access roads was 42%; potable water 10%; electricity 21%; mobile phone network 97%. All-weather roads have been greatly improved compared to 2014 (Adrien 2015), contributing to nutrition and food security through increased accessibility, exploitation and distribution or marketing of fisheries resources. Conversely, potable water (which is important in maintaining sanitation at the landing sites) and electricity are still infrequent and need speedy improvement.

Ice is the ideal, widely used chilling medium to preserve fish in both tropical and temperate environments (Cyprian et al. 2008). In the Kenyan small-scale fishery, ice is largely used for fish destined for the processing factories. In this case, flake ice is supplied through the factory agents who buy fish for the factories at the landing sites (Manyala 2011; IOC 2012). Besides, private operators produce ice in block form mainly to support the marketing of fresh fish such as tilapia and high value marine species destined to distant domestic markets, mainly in cities (Ogutu, pers. comm.). There are also local initiatives to produce ice by small-scale traders who produce small ice blocks from home freezers to handle fresh fish (Adrien 2015). This clearly demonstrates the enthusiasm and inventiveness of traders in making a living as well as contributing to nutrition through the sale of good quality fresh fish. Nonetheless, there is need to improve the hygiene and production or handling practices of ice made in this way to guarantee consumer's access to safe food.

Capacity building through stakeholders' training and provision of insulated containers/boxes for use in fishing boats and at landing sites has been completed or is underway in several projects (Adrien 2015). However, the adoption and usage of containers remains a challenge since it is limited to agents working for processing factories (Ogutu, pers. comm.). Furthermore, some of the major landing sites have several post-harvest management interventions in place. These comprise processing facilities equipped with large ice plants and cold storage (Table 3). But, several years after installation, a large proportion (84% of installed cold rooms equipped with processing units) are either incomplete or non-functional with no prospects for improvement (Oduor-Odote et al. 2014). Fresh fish for the domestic market is transported by public carriage preserved in ice using traditional baskets or insulated containers (GoK 2016). Fish preserved in this manner usually arrives in towns far from the landing sites. The businessmen dealing in such produce have moderate investments such as dedicated fish shops with deep freezers to preserve fish and improved sanitary conditions (tiled pavements and flowing water) to maintain quality standards (Ardjosoediro and Neven 2008).

4.3 Post-harvest interventions in processing

Consumers prefer fresh fish but the high perishability limits its marketing in fresh form. In Kenya, conventional fish processors use diverse but simple techniques, which depend on the market demand, quantity of fish landed, fish type and weather

Table 3 Post-harvest management intervention at landings and small scale processing sites in Kenya

Intervention	Lake Victoria (338 landing sites)		Marine coast (197 landing sites)		Others (lakes Turkana (12), Naivasha (4) and Baringo (6))		Total number of sites (557)	
	Sites installed	Sites where operational	Sites installed	Sites where operational	Sites installed	Sites where operational	% sites with intervention	% installed interventions operational
*Banda**	166	160	28	28	8	6	36	96
Cold rooms	16	2	9	2	0	0	5	16
Ice available	42	42	32	32	1	1	14	100
Jetty	20	18	15	15	0	0	6	94
Pontoon	1	1	4	4	0	0	1	100
Electricity supply	89	44	22	22	3	2	21	60
Toilet facilities	221	180	35	33	7	4	48	83
Potable water	25	25	30	30	1	1	10	100
All weather roads	146	146	81	81	8	8	43	100
Mobile network	337	337	187	187	11	11	98	100
Drying rack/solar dryer	26	2	13	4	0	0	7	15
Smoking kilns	54	20	3	1	9	5	12	39
Fish stores	41	20	20	15	0	0	11	57
Fenced	40	40	8	8	0	0	9	100
BMU Offices	160	160	30	30	8	3	35	100

*is a shaded area where initial handling facilities for fish after landing such as weighing, processing, trading and storage are undertaken

conditions (IOC SmartFish 2012). The commonly employed conventional methods are smoking, drying and deep frying (Oduor-Odote et al. 2010a, b). The use of these conventional methods is attributed to lack of installed post-harvest interventions or their non-operation at the processing sites. The end products are typically of uncertain quality owing to uncontrolled processing settings and mostly do not meet the standards of local food regulations (Kenya Bureau of Standards 2015).

In recent times interventions towards improving traditional processing methods in the East Africa region have included the training of processors and traders on handling, processing, product packaging and marketing (Oduor-Odote et al. 2010a, b; Mhongole and Mhina 2012). To avoid traditional fish drying and smoking, improved drying and smoking technologies were introduced for marine and inland lakes by Kenya Marine and Fisheries Research Institute (KMFRI) and other development partners (Table 3), and fish of better quality have been reported as a result (Oduor-Odote 2006; Oduor-Odote and Obiero 2009). Based on field observations, most of the raised racks are in poor condition and only a small proportion is utilized (15%). Improved smoking kilns are mostly utilized (39%) around Lakes Victoria, Turkana and Baringo. Generally, these post-harvest technologies have not been well adopted by processors who largely revert to their old traditional processing methods. Fish stores were also introduced as storage housings for dried and smoked processed fish products but their utility needs further investigation (Adrien 2015).

There are 15 industrial fish processing establishments in Kenya that are export orientated, categorized as land based establishments (Table 3). They largely produce chilled and frozen fish products (from small-scale fisheries) for export (Manyala 2011). These establishments have an installed capacity of 429 t per day, of which less than 150 t is utilized per day (Table 4).

4.4 Interventions' contribution or impairment to nutrition and food security

In Kenya, the evolution of fisheries from subsistence undertakings in the 1930s–1950s to the present commercial undertakings (Manyala 2011) has contributed to the nation's food and nutritional security. The evolution has ensured an expansion in fish consumption driven not only by increased production, but also a combination of many other factors; essentially, better quality, better utilization, improved distribution channels and growing demand, linked to post-harvest interventions in the fisheries sector, rising incomes and urbanization (Fisheries Bulletin 2016).

The low adoption of technologies observed in the subsector has led to continued use of conventional processing methods of smoking and drying fish under uncontrolled conditions. Smoked, sun-dried and fried fish products are the dominant processed fish products in the domestic market. Both the supply and demand of these products are to a large extent driven by insufficient cold chain

Table 4 Industrial fish processors, their installed and utilized capacities in Kenya

Name of the company	Location	Fish species processed	Installed capacity per day/metric tonne	Utilized capacity per day
*W.E Tilley (M) Ltd.	Nairobi Kisumu	Nile Perch	60	24
*East African Seafoods Ltd.	Kisumu Mombasa	Nile Perch	40	18
*AfroMeat Ltd.	Kisumu	Nile Perch	30	Closed
*Prinsal Enterprises	Migori	Nile Perch	30	20
*Peche Foods	Kisumu	Nile Perch	15	Closed
*Capital Fish (K) Ltd.	Homabay	Nile Perch	50	16
*Fish Processors (2000) Ltd.	Kisumu	Perch	25	6
*Samaki (2000) Ltd.	Nairobi	Nile Perch	25	6
*Wananchi Marine Products Ltd	Mombasa	Tuna	100	50
*TransAfrica Fisheries Ltd.	Mombasa	Octopus Lobsters Cuttlefish Squids	29	18
*Sea Harvest Kenya Limited	Mombasa	Octopus Lobsters Cuttlefish Squids	5	2.5
*Banner Distribution Ltd.	Malindi	Lobsters	10	1.2
*Crustacean Processors	Mombasa	Lobsters	0.5	0.16

*Land Based Fish Processing Establishments processing fish landed by small-scale fishers (Source: Department of fisheries Ministry of Livestock and Fisheries Development 2016 Survey)

infrastructure (Ardjosoediro and Neven 2008). The methods of processing these products may lead to loss of nutritional value as fish protein can be damaged. Processing fish by hot smoking or deep frying at fairly high temperatures such as 100 °C, as presently practiced, results in serious losses in the availability of lysine and other essential amino-acids (Kumolu-Johnson et al. 2010). On the other hand, drying under uncontrolled conditions results in contamination of products with sand, bird droppings and physical losses (Oduor-Odote et al. 2010a, b). These methods reduce nutritional value and product safety, and consequently fish contributes less towards the diet of consumers than it should or could.

Even though the adoption of improved drying technologies has been minimal, the training offered to small-scale processors, especially in fish drying, has yielded good results (IOC 2012). Unlike previous drying of small pelagic species on bare ground, the majority of processors currently dry fish on mats or fishing nets, which has somewhat improved the quality of products. This is observed in the case of Silver cyprinid (locally referred to as dagaa) which was initially utilized by the animal feed industry, but due to improved processing a higher proportion is currently used as human food (IOC 2012), contributing to food and nutritional security.

Over-investment or over-capacity in industrial processing (which depends on small-scale fisheries) described in this review has increased the demand for high value Nile perch fish (a commercially important species in Lake Victoria) as a raw material. In response, high returns (due to increased demand for Nile perch) increased investments in the small-scale fishery (Njiru et al. 2014). In the short-term, increased investment in the fishery contributed to food security as a result of improved livelihoods due to better returns and employment. However, in the long-term, continued investment in small scale fishery has caused food and nutritional insecurity (Adrien 2015). Food insecurity in parts of Kenya can be ascribed to reduced fish catches caused by over-fishing to meet high fish demand, inadequate fisheries management policies, and poor implementation of regulations.

The investment in non-functional installed infrastructure such as large cold rooms, ice plants and high capacity in processing plants that are not fully utilized as interventions in post-harvest management is perceived as a misplaced priority since they display neither prospects for improvement nor utilization. The resources used in such post-harvest interventions could have otherwise been allocated to other priority areas such as fish product development and value addition to contribute more efficiently towards food and nutritional security.

4.5 Post-harvest management intervention gaps and major drivers of change

As mentioned earlier, chilling substantially reduces the rate of deterioration of fresh fish and prolongs shelf life, thus commanding higher prices and better returns (Rawdkuen et al. 2010). This emphasizes the need to initiate the use of insulated containers and ice during fishing trips (on board fishing vessels) and harvesting in the small-scale fishery to guarantee quality and high economic returns. Unfortunately the majority of processing facilities equipped with large ice plants and cold storage for fish post-harvest management are either incomplete or non-functional with no prospects of improvement of the situation (Adrien 2015). These facilities could be utilized for ice production to be used in the upstream value chain as described earlier.

While the provision of public utilities such as access roads and electricity at fish landing sites contributes to the improvement of the national economy, inadequate sanitation infrastructure (toilet facilities and potable water among others) in most of the landing sites is bound to cause contamination of fish (Odoli et al. 2013). The quality of food products meant for human consumption must be standardized to avoid food poisoning. Government and partner agencies involved in fisheries research should disseminate research findings to stakeholders and communities in order to reduce research apathy and enhance the adoption and multiplication of technological innovations.

Adequate knowledge in the form of stakeholders' education and functional communication is important for the success of innovations (Schut et al. 2015). There are relatively low levels of education among fisher folk involved in primary fish handling in Kenya; the majority possesses only primary education (Fig. 2). Low education levels among most fisher folk in small-scale fisheries (Adrien 2015) may contribute to low economic growth in the subsector, since low education can deter the uptake of new ideas. This results in fish-for-fork rather than fish for business; most stakeholders in the Kenyan fisheries subsector have not developed a business orientated mindset (IOC SmartFish 2012).

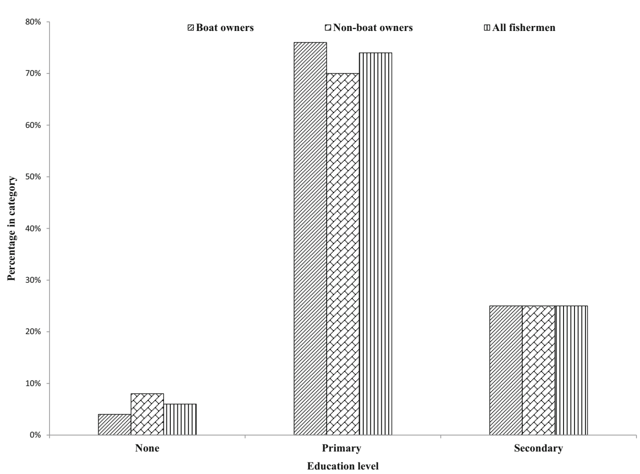
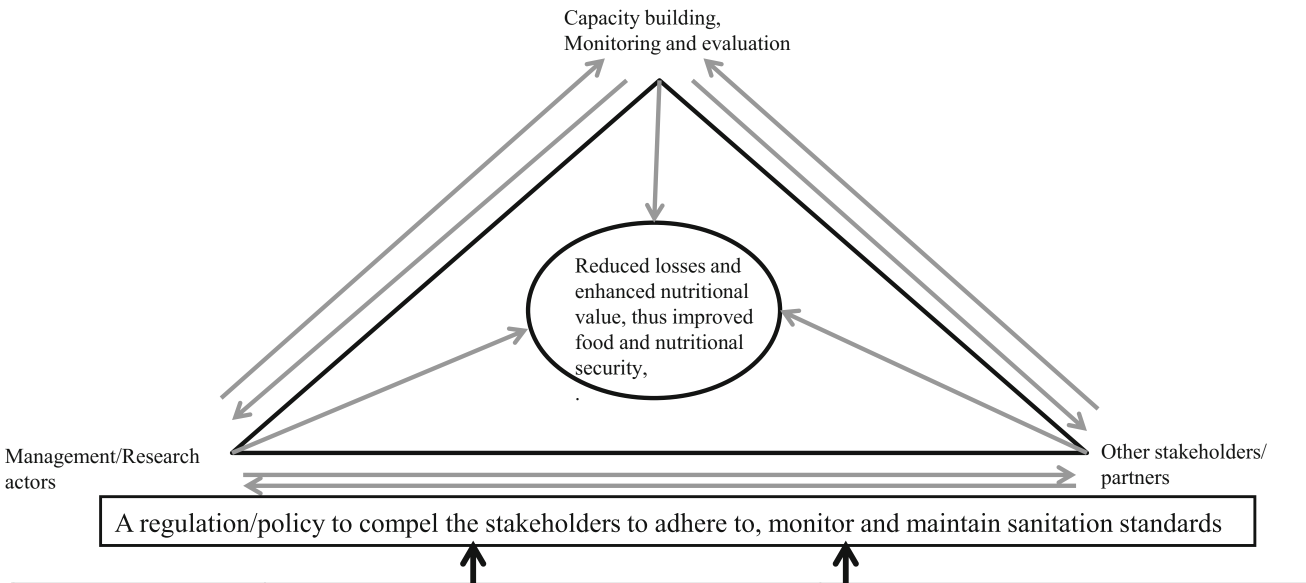


Fig. 2 Education level of fishermen in Kenya (*Source:* Adrien 2015)

Generally, instead of leaving the installed infrastructure at landing sites completely unutilized, it should be worthwhile to take advantage of some of those facilities for fish handling and processing. For instance, some fish "*Bandas*" are equipped but unused, whereas they are adjacent to old-fashioned temporary sheds, which are being used by fish mongers to process landed fish. It would be beneficial to accommodate the fish mongers within the more modern facilities for improved fish handling and sanitation. Installation of small containers at landing sites as cold storage facilities in place of large fixed equipment cold rooms could, in principle, be easily adopted to ease management and maintenance, and raise overall viability. The utilization of small containers as cold storage facilities would generate demand for ice as the chilling medium, thereby activating the utilization of moribund installed cold rooms. However, it is clear that there are still enormous needs for better water and electricity installations.

There is need for development of fisheries regulations to ensure sanitation standards required in the preparation and trading of fish foods for humans are adhered to. The successful adoption and upscaling of installed post-harvest innovations in small-scale fisheries will depend on how effective and integrative the developed policy is, i.e., accounting for interactions across different domains (economic, social, legal, and political) and institutional mechanisms that monitor and address those interactions, rigorous empirical-analytical bases for decision making, and multi-stakeholder dialogue. This is because nutrition and food security are major societal concerns that cannot be achieved without changes to whole systems of production and consumption, including social relationships, division of roles, formal rules and values, and technical artifacts and infrastructure (Mierlo et al. 2010; Schut et al. 2015). Therefore, integrating nutrition and food security objectives into traditional fisheries policies will involve confronting challenging tradeoffs among different management goals, which include ethical choices in addition to technical advancements.

Post-harvest management innovations should be supported by a monitoring and evaluation system, incorporating stakeholders' feedback to deal with uncertainties in adoption of innovations (Mierlo et al. 2010). Some of the failures in innovation uptake described in this review may be ascribed to the lack of a follow-up system to assess the actual usage and effects of the interventions. We are convinced that beneficiaries need to be more responsible, hence the need for a changed approach in the future. Beneficiaries (through their organizations, such as Beach Management Units or cooperatives) should raise initial financial contributions with the remainder being supported by the donor as part of the preferment process (Fig. 3). It would be advisable for respective authorities to assess systematically the process of introduction, adoption



Responsible organization	**Government/donors i.e. NGOs, CBO etc.**	**Community Service (CS) towards interventions**
Objective	A participatory detailed feasibility study to assess production capacity needed against demand with emphasis on implementation sites, anticipated needs linked to exploitations and management	The beneficiaries/communities (through their organisations i.e. Beach Management Units or cooperatives) raise some initial contribution and the remainder be supported as part of the preferment process .
Post-harvest management approach	Post-harvest management interventions should be well informed by the socio-economic dynamics of fishers, processors and traders to put interventions within the scope of adoption and advancement.	
Post-harvest management barriers and consequences in small scale fisheries	• Poor transportation • Conventional processing raising quality and safety issues • Poor marketing infrastructure and storage • Lack of credit facilities	• High post-harvest losses • Less nutrition/more contaminants in fish-products • Reduced profitability for processors and traders. • Low income reduces household food security, thus fishers' access to credit.

Fig. 3 Framework for post-harvest management of fish in small-scale fisheries in Kenya

and dissemination of improved technologies, as a basis for their replication or up scaling among small-scale processors (Fig. 3). To ensure such interventions thrive, the handling and processing behaviors of small-scale fishers, which provide useful dimensions in fabrication and development, can be taken advantage of by using native knowledge to ensure more acceptable and hygienic methods are employed for up scaling to enhance utility.

5 Conclusions and policy implications

Post-harvest management interventions in the fisheries sector are aimed at nutrition and food security by guaranteeing food quality and safety, nutritional aspects and reduction of waste. Underutilization of installed interventions results in continued wastage and losses of fish in Kenya, thereby contributing to food and nutritional insecurity. Post-harvest management interventions in the small-scale fishery subsector should be well informed by the socio-economic dynamics of fishers, processors and traders so that infrastructure can be adopted and advanced by the stakeholders. Prior to investment in this kind of small-scale fishery, there is need for a participatory detailed feasibility study to assess the production capacity required against demand, with emphasis on the best possible implementation sites and anticipated needs linked to their exploitation and management.

Given the relatively low educational levels within fishing communities in Kenya, knowledge has been transferred largely through apprenticeships, which are limited by memory capacities and lifespan of the traditional trainer. Formal systems of training provide a boost to memory and life span limitations through written records and books for study. Fisheries management agencies should consider formal sensitization programs that fill knowledge gaps in fish handling and processing.

From this review we recommend the development of an effective and integrative policy that entails interactions across different domains, institutional mechanisms that monitor and address those interactions, analytical bases for decision making, and multi-stakeholder dialogue for post-harvest management in small-scale fisheries. We expect that such policy will positively influence the adoption of post-harvest technology in fish handling and processing among users and custodians of the fisheries resource in Kenya.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest to declare.

References

Adrien, B. (2015). Technical report Mission to Kenya, Lake Victoria, marine coast and Lake Turkana. FAO, report final version.

Ardjosoediro, I., & Neven, D. (2008). The Kenya capture fisheries value chain : An AMAP-FSKG value chain finance case. United States Agency for International Development, 1–50.

Aura, M. C., Musa, S., Yongo, E., Okechi, J., Njiru, J. M., Ogari, Z., & Abwao, J. (2017). Towards balancing lake use and culture fisheries off Lake Victoria beaches, Kenya: Mapping and socio-economic assessment of cage culture. *Aquaculture Research, 4*, 1–14.

Béné, C., Arthur, R., Norbury, H., Allison, E., Beveridge, M., et al. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: Assessing the current evidence. *World Development, 79*, 177–196.

Bennett, A., Patil, P., Kleisner, K., Rader, D., Virdin, J. et al. (2018). Contribution of fisheries to food security: Current knowledge, policy and research. Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations, p.46.

Codex Alimentarius Commission. (2016). Code of Practice for Fish and Fishery Products. CAC/RCP 52–2003, updated 2016. Rome, FAO & WHO (also available www.fao.org/fao-who-codexalimentarius/codex-texts/codes-of-practice).

Cyprian, O. O., Sveinsdóttir, K., Magnússon, H., & Martinsdóttir, E. (2008). Application of quality index method (QIM) scheme and effects of short-time temperature abuse in shelf life study of fresh water Arctic char (Salvelinus alpinus). *Journal of Aquatic Food Product Technology, 17*, 303–321.

Cyprian, O., Oduor-Odote, P., Lauzon, H., Martinsdottir, E., & Arason, S. (2013). Microbiological quality and shelflife of fresh packaged Tilapia fillets stored under different chill temperatures. *Journal of Microbiology, Biotechnology and Food Sciences, 2*(4), 2431–2455.

Cyprian, O. O., Sveinsdottir, K., Nguyen, M. V., Tomasson, T., Thorkelsson, G., & Arason, S. (2017). Influence of lipid content and packaging methods on the quality of dried capelin (Mallotus villosus) during storage. *Journal of Food Science and Technology, 54*(2), 293–302.

FAO. (2007). Fishery country profile: Republic of Kenya. FID/CP/KEN/ FAO, Rome, Italy.

FAO. (2011). Report of FAO workshop on future directions for gender in aquaculture and fisheries action, research and development. Shanghai, China, 23-24 April 2011. FAO Fisheries and aquaculture report. No. 998, Rome, FAO. 2012; 28.

FAO. (2016). *The state of world fisheries and aquaculture 2016. Contributing to food security and nutrition for all*. Italy: Rome.

FAO. (2018). The state of world fisheries and aquaculture 2018 - meeting the sustainable development goals. Rome. License: CC BY-NC-SA 3.0 IGO. ISBN 978-92-5-130562-1.

Fisheries Bulletin. (2016). Fisheries annual statistical Bulletin. Ministry of Agriculture, livestock and fisheries, State Department of fisheries and the blue economy, Nairobi, Kenya. 66pp.

Government of Kenya. (2016). Annual report on fisheries status, State Department of fisheries and blue economy.

Gram, L., & Dalgaard, P. (2002). Fish spoilage bacteria - problems and solutions. *Current Opinion in Biotechnology, 13*, 262–266.

Huss, H.H. (1995). Quality and quality changes in fresh fish. FAO fisheries technical paper - T348.

IOC. (2012). Regional fish trade in eastern and southern Africa. Products and markets. A fish traders guide.

IOC SmartFish. (2012). Value chain analysis of fisheries sector in Rodrigues. SF/2012/18 Soobaschand Sweenarain. Agrotec.

Izraelov, M., & Silber, J. (2019). An assessment of the global food security index. *Food Security*. https://doi.org/10.1007/s12571-019-00941-y.

Kenya Bureau of Standards. (2015). Fish and fishery products (regulation No. KEBS/TC 017).

Kenya National Bureau of Statistics (KNBS). (2015). Kenya Demographic and Health Survey.

Kolding, J., van Zwieten, P., Marttin, F., & Poulain, F. (2016). Fisheries in the drylands of sub-saharan Africa “fish come with rains.” FAO fisheries and aquaculture circular no. 1118.

Kumolu-Johnson, C. A., Aladetohun, N. S., & Ndimele, P. E. (2010). The effects of smoking on the nutritional qualities and shelf-life of Clarias gariepinus (LACEPEDE). *African Journal of Biotechnology, 9*, 73–76.

Lake Victoria Fisheries Organization (LVFO) (2015). Lake Victoria (Kenya) biennial fisheries frame survey 2014 National Report. Ministry of Agriculture, Livestock and Fisheries, Kenya.

Magnússon, H., Sveinsdóttir, K., Lauzon, H., Thorkelsdóttir, Á., & Martinsdóttir, E. (2006). Keeping quality of desalted cod fillets in consumer packs. *Journal of Food Science, 71*, 70–76.

Manyala, J. (2011). Fish value chain analysis: Kenya case study. FAO-NORAD fish value chain project, 30pp.

Marsden, T., Hebinck, P., & Mathijs, E. (2018). Re-building food systems: Embedding assemblages, infrastructures and reflexive governance for food systems transformations in Europe. *Food Security, 10*(6), 1301–1309.

Martinsdóttir, E., Sveinsdottir, K., Luten, J., Schelvis-Smit, R., & Hyldig, G. (2001). *QIM- manual English version.Pdf* (p. 2001). QIM Eurofish.

Mbwana, H., Kinabo, J., Lambert, C., & Biesalski, H. (2016). Determinants of household dietary practices in rural Tanzania: Implications for nutrition interventions. *Cogent Food and Agriculture, 2*(1), 1–13.

Mhongole, O., & Mhina, M. (2012). Value addition - hot smoked Lake Victoria sardine (Rastrineobola argentea) for human consumption. In: IIFET 2012 Tanzania, visible possibilities: The economics of sustainable fisheries, aquaculture and seafood trade. Dar es Salaam, Tanzania, pp. 1–12.

Mierlo, B., Arkesteijn, M., & Leeuwis, C. (2010). Enhancing the reflexivity of system innovation projects with system analyses. *American Journal of Evaluation, 31*(2), 143–161.

Munguti, J. M., Kim, J.-D., & Ogello, E. O. (2014). An overview of Kenyan aquaculture: Current status, challenges, and opportunities for future development. *Fisheries and Aquatic Sciences, 17*(1), 1–11.

Njiru, M., Knaap, M. V. D., Nyamweya, C. S., Kayanda, R. J., & Marshall, B. E. (2014). Management of Lake Victoria fishery: Are we looking for easy solutions? *Aquatic Ecosystem Health and Management, 17*, 70–79.

Njiru, J. K., Aura, C. M., & Okechi, J. (2018). Cage fish culture in Lake Victoria : A boon or a disaster in waiting ? *Fisheries Management and Ecology, 25*(2), 1–9.

Nyonje, B., Charo-Karisa, H., Macharia, S., & Mbugua, M. (2011). Aquaculture development in Kenya: Status, potential and challenges. In aquaculture development Kenya towards food security, poverty alleviation and wealth creation. *Samaki News, 7*, 8–11.

Oduor-Odote, P. M., (2006). Improved Traditional Fish Processing Methods by Smoking and Solar Drying in Tana River and South Coast areas of Kenya. WIOMSA MARG 1 Technical Report, pp 35.

Oduor-Odote, P. M., Obiero, M. (2009) Lipid oxidation and organoleptic response during shelf storage of some smoked marine fish in Kenya.. African Journal of Food, Agriculture, Nutrition and Development 9 (3)

Odoli, C., Oduor-Odote, P., Onyango, S., & Ohowa, B. (2013). Evaluation of fish handling techniques employed by artisanal fishers on quality Lethrinids and Siganids fish genera at landing time using sensory and microbiological methods. *African Journal of Food, Agriculture, Nutrition and Development, 13*, 8167–8186.

Odoli, C., Yongo, E., Gichuru, N., Mwamburi, J., Aura, M.., Babu, M.., et al. (2017). Evaluating the effectiveness of fish post-harvest losses intervention on Lake Victoria and to guide in fish post-harvest management. Technical report KMF/ RS/2017/B2.1(vi). Kenya Marine and Fisheries Research Institute. 36 pp.

Oduor-Odote, P., Obiero, M., & Odoli, C. (2010a). Organoleptic effect of using different plant materials on smoking of marine and freshwater catfish. *African Journal of Food, Agriculture, Nutrition and Development, 10*, 2658–2677.

Oduor-Odote, P., Shitanda, D., Obiero, M., & Kituu, G. (2010b). Drying characteristics and some quality attributes of Rastrineobola argentia (Omena) and Stolephorus delicatulus (Kimarawali). *African Journal of Food, Agriculture, Nutrition and Development, 10*, 2998–3014.

Oduor-Odote, P.M., Onyango, S., Obiero, M.O., Odoli, C.O., & Ogongo, O.B. (2014). A baseline survey for marine and coastal fisheries post-harvest losses. Kenya Marine and Fisheries Research Institute. 20 pp.

Ofulla, O. A., Onyuka, J., Wagai, S., Anyona, D., Dida, G., & Gichuki, J. (2011). Comparison of different techniques for processing and preserving fish rastrineobola. *World Academic Science of Engineering and Technology, 60*, 1643–1647.

Ogello, E. O., & Munguti, J. M. (2016). Aquaculture: A promising solution for food insecurity, poverty and malnutrition in Kenya. *African Journal of Food, Agriculture, Nutrition and Development, 16*(4), 11331–11350.

Rawdkuen, S., Jongjareonrak, A., Phatcharat, S., & Benjakul, S. (2010). Assessment of protein changes in farmed giant catfish (Pangasianodon gigas) muscles during refrigerated storage. *International Journal of Food Science and Technology, 45*, 985–994.

Schut, M., Klerkx, L., Rodenburg, J., Kayeke, J., Hinnou, L., Raboanarielina, C., Adegbola, P., Ast, A., & Bastiaans, L. (2015). RAAIS: Rapid appraisal of agricultural innovation systems (part I). A diagnostic tool for integrated analysis of complex problems and innovation capacity. *Agricultural Systems, 132*, 1–11.

State Department of Fisheries (2016). Annual fisheries report, Ministry of Agriculture, livestock and fisheries, Kenya.

Tesfay, S., & Teferi, M. (2017). Assessment of fish post-harvest losses in Tekeze dam and Lake Hashenge fishery associations, northern Ethiopia. *Agriculture and Food Security, 6*(1), 1–12.

Van Nguyen, M., Oskar, J., Thorkelsson, G., & Arason, S. (2012). Quantitative and qualitative changes in added phosphates in cod (Gadus morhua) during salting, storage and rehydration. *LWT - Food Science and Technology, 47*, 126–132.

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