INTEGRATED APPROACH TO TRIGGERING A QUALITY PROGRAM IN POSTHARVEST HANDLING AND PROCESSING OF ARTISANAL FISHERY PRODUCTS

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ABSTRACT

Liberia's long coastline and rich fisheries resources offer opportunities to improve livelihoods, yet postharvest losses contribute to 59% of annual fish imports and low per capita consumption. This study identifies postharvest gaps and proposes mitigation strategies for developing an integrated quality program. Assessments included fishing vessels, processing facilities, transport methods used by fishmongers, and consumer perceptions. The findings revealed minimal use of low-temperature preservation, with over 70% of fresh fish transported without ice, highlighting access to affordable electricity and challenges to technical knowledge. Consumers prefer fresh fish and are willing to pay for improved smoked products. Policy gaps in postharvest practices have been identified in the National Fishery Policy. Key gaps were identified in the lack of electricity to maintain the cold chain, standardized smoking methods, skilled personnel for quality programs, and implementation of the relevant postharvest programs mentioned in the National Fishery and Aquaculture Strategy and Policy, including the development and enforcement of relevant technical regulations related to food safety, quality, and trade.

Keywords: Postharvest losses, fish quality programs, cold chain management, artisanal fisheries, food safety regulations, Liberia.

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ABBREVIATIONS

BNF	Bureau of National Fishery
CMA	Collaborative Management Associations
FAO	Food and Agriculture Organization
FSMS	Food Safety Management Systems
GDP	Gross Domestic Product
HACCP	Hazard Analysis Critical Control Point
ISI	International Scientific Indexing
ISO	International Organization of Standardization
MOA	Ministry of Agriculture
MoCI	Ministry of Commerce and Industry
MOH	Ministry of Health
MOU	Memorandum of Understanding
NaFAA	National Fisheries and Aquaculture Authority
NPHIL	National Public Health Institute of Liberia
TMA	Trimethylamine
TVB-N	Total volatile basic nitrogen
UL	University of Liberia
USAID	U.S. Agency for International Development

1 INTRODUCTION

Liberia has a population of 5.38 million people (Worldometer, 2022) with approximately 0.6% working in the fishery (Chu et al., 2017). The country has a coastline of approximately 579 km (Cavanagh & Veracini, 2017), bordered south-east and north-west by the Cavalla and Mano Rivers, respectively (Gershoni, 1987), and crossed by several inland bodies of water (Administration & Holsoe, 1955). Liberia has a high potential for aquaculture (FAO, 2007). Its favorable climatic conditions, abundant water resources, and good water quality make it suitable for inland farming of catfish, Nile tilapia, and other freshwater species (Kpadeh, 2011). In contrast to modern fisheries, where advanced technology is utilized, requiring fewer people, 0.6% of the overall population is relatively small to adequately exploit this fishery potential. With such vast marine and aquatic resources and a small group involved, this suggests that the fishery could fully supply the required animal protein and provide a livelihood for approximately a quarter of Liberia's population if more people become involved or if technology is applied.

It has only been five years since the Liberian fishery management system was put into perspective after 28 years of lag due to the 14 years of civil conflict that began in 1989 (Huband, 2013). The war shattered a promising fishery sector, destroyed infrastructure, and affected human resource capacity through death and migration (Wuor & Mabon, 2022). The lack of political will and capital to adequately address critical issues related to electricity and trade policies and to significantly revamp technical and tertiary institutions to address human resource capacity needs have challenged recovery. Amidst these challenges, fisheries currently provide livelihoods for approximately 10,800 full-time fishers and 22,100 local and foreign fish processors and traders (Chu et al., 2017; Sherif, 2014). It is crucial to narrow the technical and infrastructure gaps that prevent this critical sector from achieving its full potential.

1.1 Background

Fish provide approximately 15% of Liberia's animal protein supply, are the primary source of dietary protein in Liberia (NaFAA, 2020; USAID, 2015), and play a vital role in food security (Pradeepkiran, 2019). A NaFAA (2020) report states that Liberians consume about 56,315 tons of fish per year. Approximately 41% (23,199 tons) of this amount comes from local catch, and 59% (33,116 tons) constitutes the average annual imported quantity. Liberia is among the lowest in West Africa, with an annual per capita fish consumption of 11.42 kg (NaFAA, 2020). The country has a high demand for imported fish. This could be linked to licensed trawlers in Liberian waters landing their catches in neighboring countries because of the lack of suitable fishing harbors (Sherif, 2014; Wuor & Mabon, 2022). Another reason could be the under exploitation of the enormous potential of the fisheries subsector, both marine and inland, including aquaculture (Drammeh, 2007). Additionally, due to the postharvest losses marine catch faces as a result of quality issues (Jueseah et al., 2020), the sector suffers postharvest losses, comprising 22% post-landing (physical loss) and 49% of the losses occurring through

the value chain (NaFAA, 2022). Solutions to some of these challenges, including infrastructure and technology, require long- or medium-term interventions.

Vibrant human resources form the bedrock of sustainable artisanal fisheries. Regrettably, the fishing industry suffers from a lack of technically skilled human resources, as stated by the NaFAA (2022), with only 2% of individuals pursuing education beyond secondary level. This deficiency can adversely affect productivity. Under such circumstances, the economic and food security benefits of Liberia's marine resources may not accrue to the country, as well as they could, to support the livelihoods of its citizens (Wuor & Mabon, 2022). Therefore, a comprehensive strategy is required in Liberia to encourage quality awareness. This strategy intends to solve various issues that the sector is now facing, such as lack of adequate infrastructure, restricted access to suitable technology, and inadequate understanding and application of skills to manage fish quality.

Although efforts are being made to establish fishery and aquaculture training programs and construct a modern postharvest processing infrastructure, more attention should be paid to implementing sustainable quality intervention programs for locally produced fishery products. This study aims to identify gaps and address them by introducing quality programs within the fish value chain. The gaps identified will inform the development of a postharvest quality scheme, including a training manual for fish handling and processing as well as support activities to promote quality awareness in the artisanal fishery sector.

1.2 Justification

Very little is known about Liberia's quality of fish from both qualitative and quantitative perspectives or about consumers' opinions on the final quality. Jueseah et al. (2020) conducted a value chain analysis study on the seasonal flows of economic benefits in small-scale fisheries in Liberia. The study recommends policies on basic fisheries infrastructure and training to improve quality. Given the need to complement this study, it is important to first assess the specific quality gaps within the postharvest processes of fish, which are not available in literature. Understanding these quality gaps in postharvest processes will guide the development of quality programs to strengthen the technical capacity of actors along the postharvest chain, which may lead to increased income for local market production and significantly impact food security.

1.3 Research Questions

- What are the current quality gaps in postharvest fisheries?
- What impact do these gaps have, and what are the prospects?
- What sustainable quality approaches can be instituted to improve quality in the local market, increase value, and improve the livelihoods of fishermen and value chain actors?

1.4 Objective

1.4.1 General

To identify gaps and mitigation methods that will lead to the development of an integrated approach for building quality programs that influence postharvest processes and facilitate the trading of high-quality fishery products.

1.4.2 Specific

- to investigate quality activities along the postharvest processes
- to identify institutional gaps, their impact, and prospects.
- to assess consumer opinions on fish quality.
- to propose a comprehensive strategy for encouraging quality improvements in the postharvest processing of fisheries products via the application of best practices, education, and ongoing improvement projects.

2 CURRENT STATUS

The current status review of Liberian fisheries provides an overview of the quality of the artisanal fisheries. It emphasizes the current gaps, challenges, and impacts of these limitations. It concludes with the prospects and approaches that can be taken to address relevant infrastructure and technical know-how gaps and challenges, minimize postharvest losses, and improve the livelihood of fish value chain actors by observing the economic impact of the sector at the national level.

2.1 Overview of Quality in Liberian Fish processing

Quality defines the extent to which a product or service meets or exceeds customer satisfaction (Sebastianelli & Tamimi, 2002) and the characteristics of a product that are significant for consumer acceptability (FAO, 2015). As a major trade element sought by consumers, the focus is on ensuring that goods and services meet equivalent values for the price paid. Ultimately, this places the decision on quality exclusively in the hands of fish consumers (Sankar & Ashok Kumar, 2014). However, for quality to be demanded at the consumer level, there must be a net balance between purchasing power and the price increase that accompanies quality improvement.

It was deemed important to understand where the majority of fish headed after landing. This determines where the application of quality measures is required. Research findings from Jueseah et al. (2020) categorized artisanal catch trends and how they are utilized in the value chain. During the dry season, the artisanal fishery catch constitutes 86% of the total annual catch (Jueseah et al., 2020). The study further established that Fante and Kru fishers sell, on average, approximately 75% of their catch to their wives, who then process most of their products through hot smoking. Other studies have found the trade portion between fishermen

and wives to be approximately 44% (Salia et al., 2011), with variations in the value added portion (Tanner et al., 2014).

The traditional drum-smoking of fish in Liberia is similar to that performed in some West African countries. Although it is critical to classify smoking as either a value-added method or not, this process halts the processes that promote spoilage of fish in the absence of low temperatures. In the value chain analysis conducted by Jueseah et al. (2020), smoked herring was marketed at a price 47% higher than fresh herring. This may be the direct inverse for other species. The advantage of smoked products, specifically for the current population, is their longer shelf life compared to fresh products owing to the challenges of accessible and affordable electricity. Despite this, smoked fish remains susceptible to quality issues, including poor handling, preservation, processing methods, and storage facilities (Newland, 2019). Adeyeye et al. (2017) also reported an analysis of smoked fish in Nigeria and found it to be microbiologically unsafe, unless further heated or cooked before consumption. Although relevant standards and technical requirements for smoked fish products have been adopted in Liberia, the requisite authorities are yet to ensure their implementation.

2.2 Gaps and Challenges

2.2.1 Technical Knowledge

Human resources are a critical factor in building a vibrant and sustainable quality-awareness program within the postharvest value chain. In Liberia, there is a significant disparity in the technical knowledge of every sector, including artisanal fishery. Liberia has a literacy rate of 47.6% (Countrymeters, 2023). The specific artisanal fishery technical gap reported by NaFAA (2022) states that only 2% of the artisanal fishery's human resources have obtained college education. Meanwhile, 35% have completed secondary education, 18% have completed primary education, and 45% have not received any formal education. Liberia's constraint analysis strongly suggests that human capital is a limiting factor to the country's growth, development, and industrialization (Team, 2013). While some efforts have been made over the last ten years, this gap still persists in other sectors, including the artisanal fishery. The gap is evident in a World Bank report that scores Liberia’s human capital index at 0.3, only higher than two other countries globally, Chad and the Central African Republic (World Bank, 2022). The potential for economic growth may be absent or insufficient without sufficient support and investment in people at all levels (Dukuly, 2021).

The National Fishery and Aquaculture Strategy and Policy constitute important deliverables relative to capacity building for the artisanal fishery postharvest (BNF, 2014). However, only a few short training courses have been offered at long intervals, covering only a handful of the artisanal population. A few trainings had been offered by a few non-governmental organizations, including the Food and Agriculture Organization of the United Nations, in collaboration with NaFAA and the United Nations Development Program (UNDP) through the Environmental Protection Agency (EPA). They have trained over 30 and 50 fishmongers and fish processors, respectively, on "safe and improved fish handling and processing best practices" (UNDP-Liberia, 2023; EPA-Liberia, 2023).

Although several technical and vocational institutions exist in the country, they do not focus on fisheries. These institutions will be good platforms for introducing short-term quality programs. NaFAA signed a memorandum of understanding with the University of Liberia in March 2022 to establish a fishery and aquaculture training program (Browne & Hoffman, 2022). The program is expected to begin operations by mid-2023. This is a great move that promises hope to narrow the existing gap; however, short-term courses would be beneficial for current actors, as a larger number of artisanal fishery actors may not have the time or discipline to pursue a regular degree program.

2.2.2 Challenges to Infrastructure

After the end of a 14-year civil conflict in Liberia in 2003, efforts to revitalize damaged infrastructure have been impeded by poor governance. As a result of the war, the electricity infrastructure was severely damaged, making Liberia one of the countries with the highest electricity costs in Africa, at 0.553 US dollars per kWh, which is three times higher than the global average of 0.171 US dollars per kWh (GPP, 2022). According to SEFA (2013), this poses a significant challenge to the country's sustainable economic growth. The World Bank has reported that the population of Liberians with access to electricity was approximately 28% in 2020 (World Bank, 2020). Limited access to electricity results in only a small portion of artisanal catches being able to pass through the cold chain. A NaFAA report (2020) suggested that approximately 80% of the 23,199 tons of annual catch came from artisanal fishermen. In addition to the fact that 55% of the product is sold fresh, challenges to electricity are one of the primary reasons why approximately 96% of the preserved quantity is processed through hot smoking (NaFAA, 2020).

Prior to the war, the postharvest storage capacity for cold storage on land in Liberia was 6,500 m^3, with the ability to freeze 18 tons per day, and an ice plant that produced 30 tons per day (U.S. Department of State Bureau for Refugee Programs, 1991; Brainerd, 1992). This was meant to serve a population of 2.6 million people, with a city capacity of 3.8% of the total population. While the population doubled over this period, far fewer infrastructure facilities were repaired or constructed after the war, hindering much of the catch from being preserved through the cold chain, resulting in a lower market value. Several storage containers and facilities are available in Monrovia and other counties; however, they are owned and operated by foreign fish importers.

In 2016, the World Bank, through NaFAA, funded the development of a fish landing cluster facility in Robertsport, Grand Cape Mount County (WARFP, 2016). The project was in the context of an enterprise development plan for the artisanal fishery industry in Robertsport. The US$1.7 million investment facility implemented by the West African Regional Fisheries Programme (WARFP) is inclusive of a landing site, processing and storage facilities, and sales outlets. The facility lies wasted and unutilized due to the high cost of electricity to operationalize the facility and transport challenges to the market. Beneficiaries have complained about limited space and facilities being too costly to use in terms of electricity consumption (Harris, 2020).

2.2.3 Gaps in the Role of the Competent Authority and Stakeholders in the Institutional Arrangement to Secure Fish Quality

To effectively manage Liberia's fisheries, the competent authority has assigned specific responsibilities to key stakeholders in the National Fishery and Aquaculture Strategy and Policy, specifically in Appendices II and III (BFN, 2014). The policy outlines an action plan and tasks key stakeholders with managing fisheries management units, implementing the policy framework, and carrying out its various components. These include, among other things, supporting artisanal fisheries to increase the value of fish by providing facilities for ice storage on board craft; strengthening the skills of fishers and operators, especially women in fish processing, marketing, and value addition; building the capacity of the BNF for the adoption of the Codex Alimentarius for fish inspections and quality control of fish and fish products; adopting, sensitizing, and implementing capacity building on Hazard Analysis of Critical Points (HACCP) and Total Quality Management (TQM); and introducing quality, standards, metrology, and testing (QSTM) infrastructure to ensure the maintenance of set standards of quality, as mentioned in Appendix I of this paper. Appendix I highlights the gaps and responsibilities associated with the key activities required for the successful implementation of the fishery postharvest program, linking each activity to its respective stakeholders. Identified pro-quality activities within postharvest artisanal fisheries are highlighted, along with existing gaps and the impact of these gaps on quality. The identification of these gaps and their impact should inspire the development of guidelines for the successful implementation of these unaddressed activities.

2.3 Impact of Technical Knowhow and Infrastructural Gaps on Fish Quality in the Liberian Artisanal Fishery

2.3.1 Handling and Transport Methods

The quality of the finished product is influenced by the initial care provided to the fish after capture. Stress, mechanical injuries, improper bleeding, gutting, and temperature are key factors that significantly contribute to the spoilage rate of fresh fish products.

Improper bleeding threatens fish quality after catch (Rotabakk et al., 2011) and may result in the discoloration of muscles (Arason et al., 2013) and off-flavors, especially in bloody fish, by providing a good medium for bacterial growth. Almost all artisanal catch in Liberia is landed without bleeding. This suggests that fish experience a significant amount of stress when removed from their habitat before death (Kenny Down, 2015). Fish in the artisanal fishery of Liberia are not gutted. The removal of viscera, which harbor spoilage bacteria and enzymes that attack the flesh of fish after death, is important (Fernandes, 2009). Additionally, most small pelagic fish are even smoked with their internal organs, which contributes to a shorter shelf life if drying does not significantly reduce the moisture in the fish tissues.

The spoilage rate increases when major mechanical injuries are sustained (Quang, 2005). This describes physical harm as a result of human activities, such as fishing, transportation, and handling. This may expose the internal parts and underlying sterile tissues, thereby exposing fish to microbial infection. Amidst these gaps, immediate lowering of the temperature of fish is important for controlling the rate of bacterial growth and enzymatic activities (Sivertsvik et al.,

2002). However, low-temperature preservation is a major challenge because of the low accessibility and high cost of electricity in Liberia, contributing to over 90% of the preserved artisanal catch going through hot smoking (NaFAA, 2020).

2.3.2 Fish Spoilage

Chemical deterioration and microbial spoilage are responsible for an annual loss of 25% of gross primary agricultural and fishery products (Lund et al., 2000), with microbial activity alone accounting for 30% of the landed fish (Amos, 2007). Chemical processes contribute to the degradation of fish quality; however, a substantial portion of fish spoilage is performed by microorganisms, including yeast, molds, and bacteria, with bacteria being particularly responsible. These chemical processes threaten fresh products that are usually transported un-iced in Liberian artisanal fisheries.

Fish quality deterioration is a complex process that involves oxidation of proteins and lipids, endogenous enzyme activity, biochemical processes, and microbiological growth (Shahidi & Hossain, 2022). Lipid oxidation in fish tissue leads to the development of off-flavors and odors (Wu et al., 2022). Fish protein degradation and the release of total volatile base nitrogen (TVB-N), ammonia, putrescine, and histamine, are influenced by pseudomonas (Zhang et al. 2020). Aeromonas spp. and Shewanella spp. are also of major concern in fish spoilage (Sperber & Doyle, 2009; Wang & Xie, 2020), reducing trimethylamine oxides to the colorless, fishy-smelling compound trimethylamine (TMA) (Feng et al., 2021). The levels of TMA are universal indicators to determine the rate of marine fish spoilage through microbial deterioration (Ghaly, 2010).

Fish fat content, size, habitat, and exposure time are factors that may influence fish spoilage (Masniyom, 2011; Sivertsvik et al., 2002). Temperature is a key factor in controlling fish deterioration. Microorganism activity on the fish depends on the temperature, time, and conditions of storage (Heising et al., 2014; Abbas et al., 2009). Thus, the rate of fish spoilage is directly proportional to the storage temperature (Lakshmanan, 2000). Therefore, lowering the temperature below 4°C is a significant way to control the growth of microorganisms and other chemical reactions. Cold-water fish are more likely to spoil faster than warm-water fish (Abbas et al., 2009), primarily because of the difference between the habitat temperature and ambient temperature. This provides an advantage to fish products caught in tropical regions, such as Liberia, which require a comparatively higher storage temperature for cold-water fish. Value chain actors can utilize this opportunity by retaining most of the products in the cold chain.

2.3.3 Postharvest Losses

Post-harvest losses (PHL) are losses incurred between the harvest and the onward postharvest chain to markets (Buzby & Hyman, 2012). Losses range from zero utilization and product disposal (Ahmed, 2008), which is usually a physical loss (Kruijssen et al., 2020), to lower economic value owing to poor quality resulting from quality, nutritional, and market force losses (Kruijssen et al., 2020; Kumolu-Joh & Ndimele, 2011). A large percentage of physical losses within the value chain, as well as economic losses, are influenced by deterioration. This

is linked to several factors, such as waste, damage, decreased pricing, and discrepancies between a fish's potential and actual values as a result of quality decline factors, including unreliable transportation, inadequate preservation techniques, adverse weather conditions, diligence or skills of workers, species of fish, fishing gear used, types of processing methods, fish supplies greater than demand, and the market (Ward & Jeffries, 2000; Diei-Ouadi & Mgawe, 2011; Ambler et al., 2018; Wibowo et al., 2017).

Fish and fishery products are highly perishable commodities that are influenced by enzymatic and microbial interactions, and chemical influences that may result from these activities (Zhuang et al., 2021; Ghaly, 2010). Therefore, the quality of the final product depends on the handling and processing of raw materials (da Silva, 2002), primarily by maintaining a lower temperature through icing, as well as on the processing environment, packaging, and microbial stability (Perera, 2005). The value of fish can be affected by poor quality (Jueseah et al., 2020), especially when better-quality options are available (Kruijssen et al., 2020). This could have a socioeconomic impact on the livelihood of the actors. According to Jueseah et al. (2020), artisanal fishermen face diverse seasonal challenges. However, irrespective of the season, the study also found that by improving quality through gutting, descaling, and icing, the fish value increased by 8% to 38%. This indicates that the income of fishing communities in Liberia can be increased and seasonally stabilized if the factors that challenge postharvest losses are adequately addressed.

2.3.4 Economic Impact

The economic impact that the artisanal fishery suffers from is a combination of gaps in knowledge and infrastructure and the implementation of stakeholder responsibilities within the Fisheries and Aquaculture Strategy and Policy.

Between 2014 and 2020, on average, Liberia exported 123 tons, which is approximately 0.4% of its equivalent imports of 33,116 tons (NaFAA, 2020). The volume of imported fish could be minimized if the lost portion was retained through the institution of a sustainable quality program in the handling and processing of fish. A value chain analysis of the seasonal flows of economic benefits in small-scale fisheries in Liberia conducted by Jueseah et al. (2020) indicated a 60% higher benefit gained as a return on investment for fresh fish traders compared to fishermen. Compared to fresh fish traders, processors benefit 50% less (Jueseah et al., 2020). It is not clear whether this relates to consumers' choice of fresh products or to the quality of smoked products. However, the market demand for fresh products is 9.8% higher than that for smoked products (Onyia et al., 2014), and findings have shown that smoked fish is the preferred alternative to fresh fish in Nigeria (Afolabi et al., 2007). Challenges exist in maintaining a cold chain to reach all fresh products to consumers, ensuring quality handling procedures, and improving processing methods, which may increase demand and market value (da Silva, 2002).

2.4 Prospect and Approach

2.4.1 Regulatory frameworks

The competent authority in the National Fishery Strategy and Police (BNF, 2014) established regulatory frameworks that assigned responsibilities to relevant stakeholders to set standards and technical regulations for fish quality, processing, and storage. There is a need for relevant adopted standards, for example, the standards quoted in Table 1, that are applied conformity assessment instruments of the Liberia Standards Authority, to be developed into technical regulations for application. The Fishery and Aquaculture Authority proposed the development of fish product regulations in its 2014 strategic policy; however, this has yet to come into motion.

2.4.2 Industrial Standards

It is imperative that the implementation of relevant quality programs in postharvest artisanal fisheries be guided by standards. With the application of set standard requirements, the production of safe and quality products could be guided to ensure that fish products meet regulatory standards and satisfy the quality demands of consumers.

The Liberian Standards Authority, in collaboration with the Ministry of Commerce and Industry, has adopted regional and international standards for fish products. The standards are listed in Table 1, which contains the relevant internationally adopted standards for fish and fishery products. Regional and international standards for fish products have been adopted in collaboration with the Ministry of Commerce and Industry. These are voluntary standards that can be applied by fish processors to meet customer demands for quality. The extent to which standards are expected to be applied in the processing industry depends on consumer awareness of the standards and how their application will guarantee the quality of the products they demand. This will trigger a demand for processors to apply standards to meet customer satisfaction. These standards are available at the "Standard Desk" of the Liberian Standard Authority.

Table 1. Fish Quality Related Standards

Code	Standards
LS/CAC/RCP 47-2001	Code of Practice for Fish and Fishery Products
LS/CAC/GL 48-2004	Model Certificate for Fish and Fishery Products
LS/ECOSTAND 5:2013	Standard for quick frozen whole fish
LS/ECOSTAND 6: 2013	Code of practice for fish and fishery products
LS/ECOSTAND 9:2014	Standard for quick frozen fish filets
LS/ECOSTAND 10: 2014	Standard for smoked, smoke-flavored, and smoke-dried fish

2.4.3 Conformity Assessment (Inspection, Testing, and Certification System)

Inspection, testing, and certification are the three components of conformity assessment. To effectively drive and sustain a quality awareness program, it is important to institute minimum

standards within the postharvest artisanal fishery and regulations to enforce compliance with best practices.

Inspection: In the postharvest context, the National Fishery and Aquaculture Authority has an inspection team that primarily focuses on the inspection of storage facilities for imported frozen fishery products. Technical regulations related to the minimum requirements for small, medium, and large fish processing and storage facilities are missing. Imported frozen products purchased by fishmongers are sold on the market during the day and smoked overnight after defrosting because of the lack of commercial cooling facilities and/or high cost of electricity. This adds up to the existing 45–80% of marine catches that are processed through hot smoking.

Testing: The National Fishery and Aquaculture Authority has a fully furnished testing laboratory that is primarily suited for microbial analysis, with chemical methods limited to a few rapid tests. A few gaps exist, including the installation of the quality management system, accreditation of the laboratory, and training of staff in microbial test parameters. Training of the staff in microbial test parameters can be achieved through institutional collaboration. Under the Liberia Standards Authority, the National Standards Laboratory of Liberia has trained professionals and experienced microbiologists who can transfer their knowledge to NaFAA technicians to narrow the technical gap.

Certification: The Fisheries and Aquaculture Strategy and Policy has referenced the Standards Board (Liberia Standards Authority) in collaboration with the Ministry of Health (MOH), with the responsibility of ensuring the sanitary certification of fish through a competent laboratory. The roles are not clearly defined; however, the responsibilities of the Liberia Standards Authority entail development, making available and accessible relevant food safety and inspection standards to be applied in the industry, including postharvest processing of fish. A certification scheme needs to be developed through the collaboration of the three institutions.

2.4.4 Education and Outreach Programs

Media propagation of fishery activities is minimal. In 2021, however, the Environmental Justice Foundation (EJF) trained journalists from four coastal counties on *fishery reporting* to create public awareness of the fishery sector and its meaningful impact on the livelihoods of Liberians (LINA, 2021). Additionally, more awareness of quality is needed to provide consumers with an understanding of what it is and what it should be. Media institutions, civil society groups, and those involved in advocacy for consumer protection must be incorporated into the development of educational and outreach programs to promote best practices for fish handling, processing, and storage, as well as consumer education campaigns.

2.4.5 Regulated Activities

Key activities within the postharvest period of artisanal fisheries, including handling, processing, packaging, labelling, transportation, and storage, are not regulated. Postharvest inspectorate programs in NaFAA have focused on imported fish storage facilities. The fish quality standards (Table 1) are a good standard tool that can be transformed into technical regulation for regulatory purposes.

3 METHODS

3.1 Study Site

The study was conducted at Point Four, a fishing town in Montserrado County near Monrovia (approximately 7 km from the capital), and Marshall in Margibi County (approximately 53.9 km from the capital). The two study sites were urban and remote/semi-rural fishing locations, respectively. The rationale for selecting the two sites is based on a previous study by Jueseah et al. (2020), who reported a huge gap in postharvest losses between fishing localities in urban and rural areas. These locations were the most convenient based on distance and available resources and contained all the elements (landing sites, Kru and Fante fishermen, artisanal fishing culture, and accessible fishmongers and processors) that this study sought to investigate.

Figure 1. River Map of Liberia and Geographical Location of Surveyed Fishing Communities (Point Four, Montserrado and Marshall, Margibi). Source: Mapsofworld.com.

3.2 Materials

Questionnaires were used for data collection, and a description of the set of questions is provided in Section 3.4. An interview guide that supported the data collection was explained prior to the collection process. Due to the educational status of the respondents, verbal consent to participate was requested. An electronic data collection tool using Google Forms was created and used with the instructional support provided to the respondents without influencing their responses.

3.3 Study population and sample size

Two major landing sites in two counties (Montserrado and Margibi) were used, representing two out of the nine coastal counties. This study targeted fishermen, processors, fishmongers, and consumers. Montserrado has 4,133 fishermen and seven landing sites, with an average of 590 fishermen per landing site (NaFAA, 2020). Margibi also has 612 fishermen and four landing sites, with an average of 153 per landing site (NaFAA, 2020). Table 2 shows the population and sample size of the fishermen. Fishmongers and processors cut across all landing sites in their respective countries. Therefore, the population of fishmongers and processors mentioned in Table 3 is the total population of the counties. While there are actors involved in

both activities, the choice of respondents was selective to assess specific information relative to each actor in the study areas. The sample included 43 fishermen (interviewed from different fishing vessels), 38 fishmongers, 31 fish processors, and 124 consumers at the market level. In total, 263 respondents were included in the survey.

Table 2. Sampling Size for Fishermen (Fishing Vessel)

Fishing Site	Fishermen	Sample Size	Percent
Point Four	590	24	4.0
Marshall	153	19	12
Total	743	43	5.7

Table 3. Sampling Size for Fish Processors and Fishmongers

Actors	Margibi-Marshall	Montserrado-Point Four	Total	Sample size	Percent
Fishmongers	161	1316	1477	31	2.1
Fish Processor	175	35	210	38	18.1
Total	336	1351	1687	69	4.1
Sample	28	41	69	--	--
Percent	8.3	3.0	4.0	--	--

3.4 Data Collection

The data were collected using questionnaires. Respondents were interviewed using questionnaires with the support of the interviewer in reading the questions in the simplest way possible. The nature of the questions considered respondents' educational status. The questionnaires for fishermen, fishmongers, processors, and consumers contained 21, 28, and seven questions, respectively. Depending on the nature of the questions, the questionnaire contained two to six options and short responses.

3.5 Data analysis

Excel statistical tools were used to design tables, graphs, and data analyses.

4 RESULTS AND DISCUSSION

The findings from the study conducted among 43 fishermen, 38 fishmongers, and 31 fish processors are summarized in Table 4. The table is divided into five categories that address issues, including gaps in the cold chain, capacity, time utilization, food safety, and trade-related issues. It shows the gaps in catch processing and transportation to consumers and presents a concise summary of the findings listed in detail in Appendices VIII and IV.

According to the scale matrix, pointing to the key quality indicators, the management of catch along the cold chain is poor. The findings presented show that storage containers are not utilized by fishermen, which supports the fact that ice is not taken onboard their fishing trips, according to the findings. The resulting impact is the direct exposure of products to sunlight and the increased likelihood of sustaining mechanical injuries such as being stepped on by fishermen during the process of retrieving a cast net. This may also result in the product being kept in unsanitary conditions on the floors of fishing vessels, increasing the risk of bacterial infection in the absence of ice to slow down the rate of deterioration.

Table 4. Key Quality Gap Assessment of Onboard Handling, Processing & Transport.

N⁰	Interviewees Response to Key Infrastructural and Technical Indicators	Performance Status (Percent)		Scale			
		Onboard Handling	Processing & Transport	Excellent	Good	Average	Poor
1.0	**Cold Chain Gaps**						
1.1	Usage of storage container onboard	4.7	---				
1.2	Onboard icing	0.0	---				
1.3	Icing status of landed catch/transported catch to facility	0.0	0.0				
1.6	Fresh product transported to market on ice	---	27.1				
1.7	Portion of fresh product chilled or frozen	---	1.4				
2.0	**Capacity Gaps**						
2.1	Actors with history of any form of training	18.6	23.2				
2.2	Actors trained in fish handling	7.0	18.8				
2.3	Actors trained within the last two years	25	69				
3.0	**Time Impact Gaps**						
3.1	Duration at sea < 5 hrs.	23.3	---				
3.2	Time frame negotiating sales (< 30 mins.)	67.4	---				
3.3	Transport period from landing to processing site (< 30 mins.)	---	66.7				
3.4	Preparation period before processing (< 30 mins.)	---	48.5				
4.0	**Food Safety Gaps**						
4.1	Legal registration (Business registration)	---	1.4				
4.2	Processing facility in an enclosed structure	---	2.7				
4.3	Facility built to limit risk to cross contamination	---	2.7				
4.4	Status of installed FSMS or HACCP[1]	---	4.5				
4.5	Documentation of processing processes	---	**0.0**				
5.0	**Trade Related Issues**						
5.1	Portion of fish sold fresh	---	30.4			N/A	
5.2	Portion of fish hot smoked	---	68.1			N/A	
5.3	Storage temperature of smoked product RT[2] (26-28 ^{0}C)	---	100			N/A	
5.4	Local market as primary customers	---	95.7			N/A	
5.5	Fish shipping/export history	15.4	---			N/A	

Scale Matrix:	*Excellent*	*Good*	*Average*	*Poor*	*N/A*
	75-100	*50-74*	*25-49*	*<25*	*Not Applicable*

[1] Food Safety Management System or Hazard Analysis Critical Control Point
[2] Room Temperature

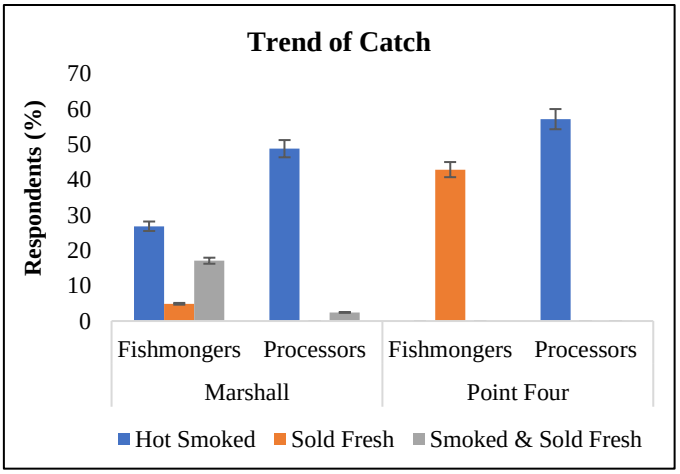

Figure 2. Trends in Landed Catch

Significant quality deficiencies were observed along the value chain concerning the handling and processing of the catch. The findings show that over 60% of the respondents agreed to smoke their products. About 21.7% of the respondents trading fresh products claimed to have iced products transported to markets or end users; however, this does not suggest that the actual percentage of fish quantity falls in this category. A NaFAA (2020) report, however, mentions the average quantity of fish iced across the country at 15.7%. More respondents affirmed trading fresh products at Point Four than at Marshall. This could be because Point Four is closer to the main market. On the other hand, Figure 3 indicates that a greater number of respondents agreed to transport products on ice from Marshall than from Point Four. This can be attributed to the fact that unlike Point Four, Marshall is located on the outskirts and requires a longer travel time.

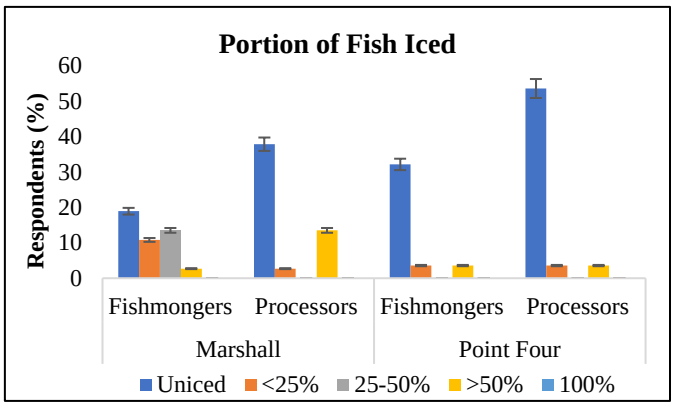

Figure 3. Icing Status of Fresh Catch Transported to Market

The high percentage of respondents agreeing to smoke their products is due to several factors, including the distance of landing sites from the city, lack of a good road and transport network, vessels landing at later hours, which constrains consumers from getting fresh products, and consumers' preference for certain species, such as herring, to be smoked. However, the percentage of fresh fish sold in the market is much higher for populated or urban landing sites, such as Montserrado and Grand Bassa, than for rural landing sites because of the huge demand for fresh products.

Unlike Marshall, almost all of the fish transported from Point Four, either by fishmongers or processors, reached the consumers or processing facility un-iced. A small portion of fresh products is transported on ice by fishmongers in Marshall. While the findings showed that 95.7% of fishmongers sold their products to the local market, there is doubt about the suppliers of hotels, restaurants, and other eateries. The Korean wholesalers, a small group of fishmongers noted for avoiding participation in surveys, usually trade cassava fish (*Pseudotolithus senegalensis*) and add value to the product, ice, and transport it to foreigners with a 50–90% profit margin compared to fishermen's wives who smoke and sell (Jueseah et al., 2020). They may likely be one of the suppliers to hotels and restaurants, owing to the fact that restaurants, hotels, and other public food eateries will typically pay higher prices for fish products, but one of good quality. Unfortunately, the current handling methods from catch through the value chain may not meet the minimum requirements of these high-value customers.

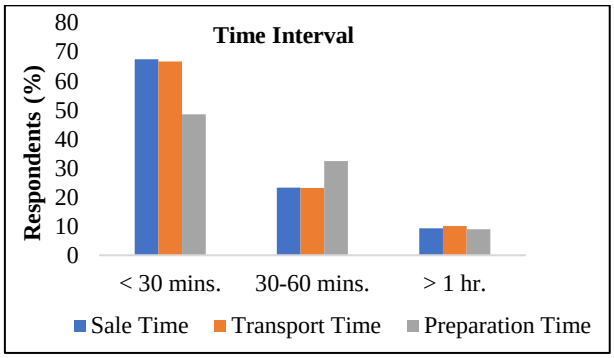

Figure 4. Time interval from landing of catch to market or readiness for smoking.

The quality of a fresh product is a factor of time and temperature. When the cold chain is broken, the quality of the fish is threatened, particularly in instances where time cannot be controlled. For example, the study discovered that 76.7% of fishermen spent more than 5 hours on a single fishing trip, with time ranging from 5 to 15 hours. A similar study in the Gulf of Nicoya found that 73.3% of fishermen fished for more than 6 hours, ranging from 6 to 16 hours (Chavarra et al., 2017). Because fishing time cannot be controlled, having ice onboard becomes imperative to maintain a lower temperature that would guarantee landing good-quality products. Figure 4 illustrates the various time intervals involved in handling a catch following its landing. The graph depicted in the figure indicates that most of the respondents handled the catch within 30 minutes after landing, at different time intervals. On the aggregate time interval from landing and trading, transporting to processing facilities or markets, and preparation (gutting, descaling, and cleaning) until hot smoking, more than 50% of the respondents reported a time of less than 30 minutes. This is because most of the processing facilities are within 1–2 kilometers of the landing sites; however, in the dry season, when there is a surplus of supply, demand is affected, resulting in a prolonged period to locate a buyer and negotiate sales. At the same time, the supply outweighs the processing capacity for processors, resulting in high losses.

Weighing scales are not used in the artisanal fishery for price determination; therefore, the quantity of fish is negotiated between fishermen and buyers. The National Fishery and Aquaculture Strategy and Policy, cited in Appendix I, involves the Liberia Standards Authority, which originated from the Ministry of Commerce and Industry, in establishing quality,

standards, metrology, and testing (QSTM) infrastructure to uphold the prescribed standards of quality. The program's expected role is to address and lead the approach to setting quality- and trade-related standards. Introducing weighing scales for trade purposes would be a good approach for stabilizing prices and promoting fair-trade. This could help keep track of the quantity of landed catch and minimize trading time.

According to the findings (Table 4), not only is the educational level of the actors low, but basic training on appropriate fish handling and processing techniques is also lacking. These gaps are, however, part of the key deliverables of the Fisheries and Aquaculture Strategy and Policy (Appendix I), strengthening the skills of 10,000 fishers and operators by 2014 to 2030, as well as 3,000 operators, especially women, in fish processing, marketing, and value addition. These findings indicate how minimally this approach has been implemented. With appropriate technical expertise, products not fit for direct consumption due to spoilage could be utilized by other means to minimize losses.

It is important to point out that technical regulations and standards are important for ensuring product safety and quality. While standards are voluntary, they play a significant role in expanding products and services as well as increasing profitability through adherence to consumer opinion. However, technical regulations that should ensure appropriate measures are in place in the postharvest artisanal fisheries are missing. This points to the findings (Table 4) revealed in the current study, showing that only 2.8% of processing facilities are legally registered. Legal registration of food processing establishments is a crucial step towards the inspection and monitoring of compliance. Establishing the legality of participating enterprises is crucial for developing quality programs. The findings further show that facilities used for processing are not standardized and are built with limited access restrictions, for example, to animals. Only 8.1% of respondents affirmed the installation and application of the Food Safety Management System, or HACCP, in their facilities. However, there must have been a misunderstanding, as none of the respondents laid claims to documenting all the processes in their facility, which is a key element of ISO 22000 or HACCP.

The National Fishery and Aquaculture Strategy and Policy, found in Appendix I, designates the Liberia Standards Authority (MoCI) and the Ministry of Health as responsible for enhancing the capacity of NaFAA to implement the Codex Alimentarius for fish inspection and quality control of fish and fish products. The same table specifies that the Liberia Standards Authority (MoCI) is assigned to carry out the adoption, awareness-raising, and implementation of capacity building on Hazard Analysis of Critical Points (HACCP) and Total Quality Management (TQM) for postharvest fisheries. Unfortunately, the full operation of the Liberia Standards Authority has been impeded by political challenges.

Table 5. Consumer Opinion on Fish Quality (124 respondents)

Nº	Key Quality and Consumer Satisfaction Indicators	Respondents Grading	Respondents Scores (Percent)
1	Quality preference for fish product	Frozen	50.8
		Fresh	48.4
		smoked	0.8
2	Factor influencing choice	Cheap/affordable	13.7
		Good quality	46.8
		Option available in local market	39.5
3	Quality rating of smoked product	Very good	13.7
		Good	71
		Okay/ Fair	15.3
4	Consumer satisfaction of smoked product	Yes	17.7
		somewhat	45.2
		No	37.1
5	Related smoke fish issues	Fragmented, broken	81.5
		Maggot	1.6
		Mold	8.9
		Sand	8.1
6	Consumers' willingness to pay for improvement	Yes	88.7
		No	0.8
		Maybe, not sure	10.5

To establish a strong program for enhancing postharvest quality in artisanal fishing and maximizing profits by adding value, it was essential to evaluate consumer feedback and prioritize addressing specific deficiencies that affect their satisfaction. Fish products on the Liberian market include frozen imported, fresh marine, and hot-smoked fish. A small quantity of freshwater fish caught in the wild or grown in aquaculture is sometimes available, but this was not the focus of this study.

The findings (Table 5) focused on consumer issues relative to quality preference, factors influencing choices, quality rating, consumer satisfaction, related quality issues, improvement required for smoke fish processing, and willingness to pay for improvement. Consumers play a significant role in driving demand for quality products. However, in an economy where poverty is prevalent, purchasing power is a challenge, making it difficult to choose high-quality products. An increase in demand for quality often leads to a corresponding increase in prices, negatively impacting consumers' purchasing power. This situation results in a preference for cheaper protein sources, such as poultry products, contributing to a decline in consumer preference for fish.

In this study, consumers showed a very high preference for raw (fresh and frozen) products over hot-smoked products and comparatively for fresh and frozen products (Table 5). Interestingly, consumers' choices are influenced by various factors. According to Figure 5, consumer preferences for local and frozen imported products are primarily based on the quality and options available in the local market.

Figure 5. Consumer preferences and factors influencing choice.

Less than 8% agreed that their choices were influenced by the price. This means that consumers may not choose frozen products when fresh local products are available, which is hardly the case, as most products are hot smoked because of the high cost of maintaining the cold chain.

Despite consumers' low preference for smoked products, all consumers ate smoked products and rated their quality as good (71%). A few factors that challenge the quality of smoked products (Table 5) include fragmentation (broken), maggots, mold, and sand, with 81.5% ascribing fragmentation as a major quality concern. The impact may have been influenced by various factors, such as poor transportation, improper drying, and poor handling during the marketing process. Although consumers expressed less preference for smoked products, they expressed a strong desire for quality improvement, as shown in Table 6. As shown in Table 5, 88.7% of the respondents were willing to pay for improvements. The overall reaction of consumers supports the claims of Afolabi et al. (2007) that smoked fish are the preferred alternative to fresh fish.

Table 6. Consumers' Perspective of What Processors Need to Improve

Consumers' perspective	Frequency	Percent
Reduce the fish price	42	34
Reduce the fish price and improve quality	48	39
Improve quality	34	27
Total	**124**	**100**

Table 6 shows that more consumers (39%) want the quality of the product to increase but want the price to decrease. This further shows that 34% of consumers are exclusively concerned about price reductions.

As previously mentioned, 43.2% of the artisanal catch was hot-smoked, as reported by NaFAA (2020). The data in Table 4 shows that all smoked products were stored at ambient temperature (RT [1], 26–28°C). However, it is difficult to determine how this poses a threat to quality and contributes to losses, as data on the proximate analysis of smoked fish products are unknown. It is important to determine, for example, the moisture content of the fish, which will inform the appropriate storage conditions and help predict the shelf life of the final product. To achieve this, standardizing the smoking method to ensure uniform drying of both lean and fatty fish is

required. For example, cutting larger fish into specific shapes (Figure 5 and Figure 6) before drying can significantly affect the drying process, leading to a more thoroughly dried end-product.

Musca domestica, a housefly commonly found in unsanitary environments and attracted to decaying materials, is a major threat to improperly dried smoked products. Smoked products are usually not vacuum-packed and are openly displayed on local market tables, increasing exposure to vectors. The fly lays eggs on the fish, which freely develop into parasitic maggots at an ideal temperature because the fish are not refrigerated, causing rapid deterioration. This is the foundation of the analysis of Adeyeye et al. (2017) of smoked fish in Lagos State, which found them microbiologically unsafe unless further heated or cooked before consumption. However, it is strange that consumers do not view this as a major problem.

Figure 6. Horizontally cut smoked fish, limiting surface area (Source: Matakana Smokehouse)

Figure 7. Vertically split smoked fish, facilitation easy dying (Source: Smith, 2021)

Improving access to markets for fish products by maintaining standards, market data, and road transport networks is one of the activities outlined in the National Fishery and Aquaculture Strategy and Policy Implementation Plans (Appendix I).

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study identified key gaps in the postharvest management of the artisanal fishery, in line with its objective. It was predicted that the right quality programs to strengthen the technical capacity of actors along the postharvest chain and address relevant infrastructural gaps could only be developed if an assessment identified quality gaps within the postharvest processes. Findings from the study proved that the artisanal fishery sector lacks the requisite human resources to drive productivity and realize its full potential. However, this can be achieved over time by using a sustainable capacity development program. This study uncovered key gaps linked to electricity in maintaining a cold chain that would minimize postharvest losses, standardized quality methods that would produce high-quality products, developed human resource capacity that would champion quality schemes within the sector, and lapses in the implementation of relevant postharvest programs mentioned in the National Fishery and Aquaculture Strategy and Policy. The current status of postharvest activities within artisanal fisheries can be scaled up when the proposed recommendations are adhered to and fully implemented.

5.2 Recommendations

This study proposes both long- and short-term measures to address gaps that hinder the potential of postharvest artisanal fisheries. These measures are recommended to competent authorities and relevant stakeholders as follows:

Short term:

a) Support the development and implementation of a sustainable training and quality promotion program.
b) Convene a technical stakeholder engagement to review, recast, and implement the postharvest deliverables within the National Fishery and Aquaculture Strategy and Policy.
c) Enforce technical regulations related to food safety and trade.
d) Develop a sustainable fish processing scheme and value-added marketing plans.
e) Develop a standardized smoking method.
f) Develop an inspection framework and certification scheme.
g) Develop the technical capacities of laboratory analysts to run a competent laboratory.
h) Generate data on the proximate analysis of smoked fish products through testing.
i) Develop an access-to-finance strategy.

Long term:

a. Accreditation of the competent laboratory
b. Access to affordable electricity
c. Dragging of the harbor

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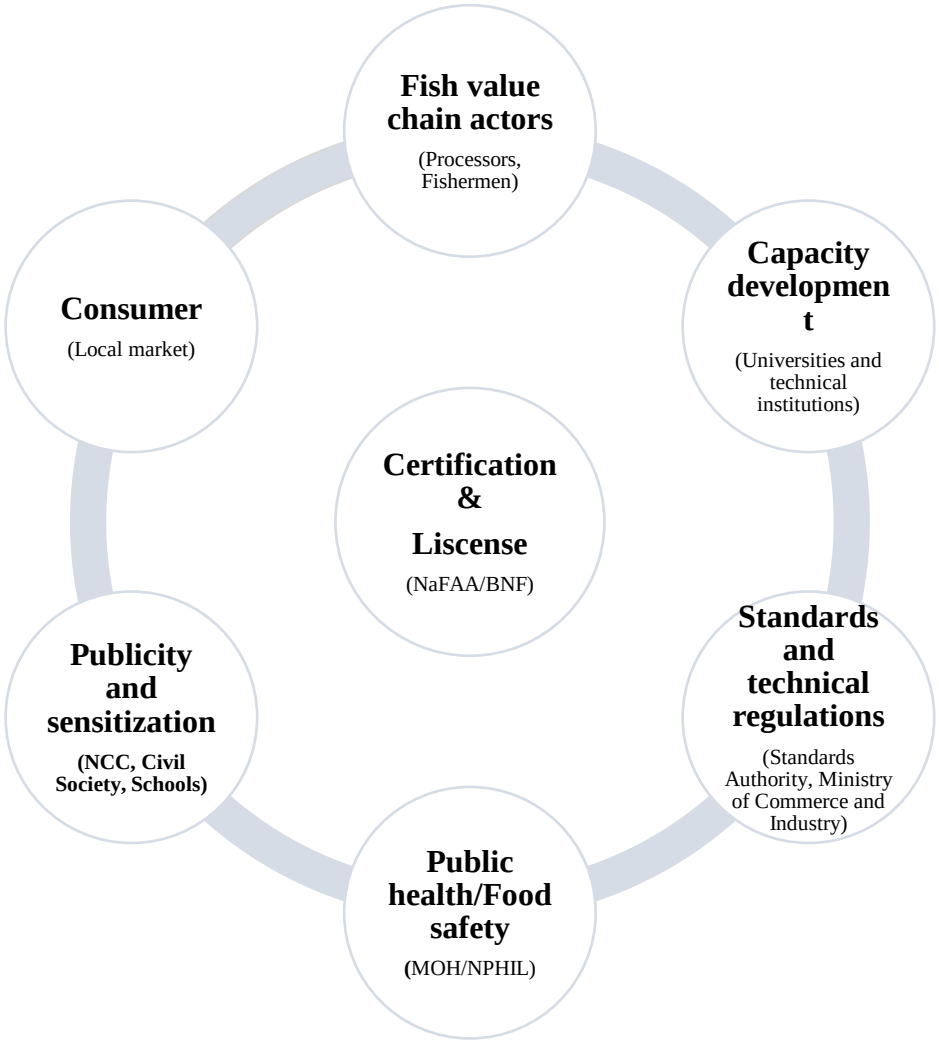
APPENDICES

Appendix I Gaps and Responsibilities of Key Stakeholders within the Fisheries and Aquaculture Strategy and Policy (FASP)

No	Post-Harvest Sector		Post-harvest Pro-quality Activities	Gap	Resulting Quality Impact	Relevant stakeholders	Key Post-Harvest Deliverables 2014-2030	Reference Fishery Policy				Status
								Appendix	Objective	Strategy	Action	
1.0	Fishing/Harvesting		Onboard Icing Storage	Knowledge (training) & Ice storage	Spoilage from Bacterial growth, enzymatic reactions, and Histamine formation	NaFAA, MOA, CMA LiSA	Support the artisanal fisheries to increase the value of fish by the provision of facilities for ice storage on board craft.	III	4	1	3	NI
			Proper Fishing method, Appropriate gears, & Proper Handling	Knowledge (training)	The mechanical force causing tissue damage and bruising can result in the infiltration of bacteria into sterile tissues.	MOA, MoCI/LiSA, CMAs	Strengthening the skills of 10,000 fishers and operators	II	--	--	--	NI
			Pre-processing (Bleeding)	Knowledge (training)	Dark muscles/discoloration, Off-flavors							
2.0	Transport fresh products from the landing site	Processing facility	Icing of catch	Icing infrastructure	Spoilage from Bacterial growth, enzymatic reactions, and Histamine formation	NaFAA	Support the artisanal fisheries to increase the value of fish by the provision of facilities for ice storage on board craft.	III	4	1	3	NI
						MOH, MOCI/LiSA	Build the capacity of the BNF for the adoption of the Codex Alimentarius for fish inspections and quality control of fish and fish products	III	4	2	2	NI
		Market	Icing of transported catch	Ice storage			Support the artisanal fisheries to increase the value of fish by provision of facilities for ice storage on board craft.	III	4	1	3	
3.0	Processing facility	Smoking, Chilling/ Freezing	Good gutting, fileting, & descaling skills;	Knowledge (training)	Poor quality (low-value product), post-harvest losses	MOH	3,000 operators, especially women, trained in fish processing, marketing, and value addition	II	--	--	--	NI

		Product testing; Icing Storage,			MoCI/LiSA,	Adopt, sensitize and implement a capacity building on Hazard Analysis of Critical Points (HACCP) and Total Quality Management (TQM).	III	4	2	1	
					(NaFAA, CMAs)	Introduce quality, standards, metrology, and testing (QSTM) infrastructure to ensure the maintenance of set standards of quality.	III	4	2	4	
4.0	Conformity Assessment	Inspection	System, Knowledge (training)	Unhygienic production environment, facility and untrained and inexperienced personnel	NaFAA,	Build the capacity of the BNF for adoption of the Codex Alimentarius for fish inspections and quality control of fish and fish products	III	4	2	2	
		Testing		Uncertainty about the quality and safety of the finish product	NaFAA,	Establish a national competent laboratory at Mesurado for certification of fish.	III	4	3	3	
		Certification		Risk of being devalued, and rejected	NaFAA,						
5.0	Transport to market	Proper storage and packaging	• Knowledge (training) • Ice storage	Poor quality (low-value product), post-harvest losses resulting from spoilage	BNF, CMA, MOCI/LiSA	Encourage packaging and develop fish products that add value to fish and fish products	III	4	3	1	
6.0	Handling at the market level	Proper storage	Knowledge (training)								
7.0	Subsidy to support quality management and complement seasonal challenges	Quality sustainability	Funding/subsidy	Breakdown of quality system	BNF	5000 operators benefiting from credit schemes annually	II	--	--	--	NI
8.0	Consumers	Feedback on quality	Perioding survey on consumers' opinion on quality	Unknown aspect of the fish quality requiring improvement	MPW, BNF, MCI, SB, LISGIS, LMA	Improve access to markets for fish products by maintaining standards, market data and improvement of road transport networks	III	2	3	4	

NI: Not Implemented; FI: Fully Implemented; O: Ongoing



Appendix II Key stakeholders and role in instituting a sustainable fish quality program

Appendix III Key Quality Gaps in Onboard Fish Handling

Question	Response				
Do you use a storage container onboard	**Yes**		**No**		**Sometimes**
	4.7		95.3		0
Do you take ice onboard?	**Yes**		**No**		
	2.3		97.7		0
Status of landed catch	**Negotiate sale**	**Sell to Wife**	**Sell immediately**		**Sell Out or to my wife**
	4.7%	14%	72.1%		9.2%
Duration at sea	**1-5 hrs**	**6-10**	**11-15**	**16-24**	**2**
	23.3%	46.5%	27.9%	0%	2.3%
What is your vessel house power	**Motioned by Peddle (< 8 HP)**	**8-15**	**16-25**	**26-40**	**> 40**
	46.5	37.2	4.7	11.6	0
Have you received any form of training on how to handle your catch?	**Yes**		**No**		
	18.6		81.4		
Training Kind	Fish handling techniques		Gear deployment, retrieval, and navigation		**Non**
	7		**11.6**		**81.4**
When did you take the training	**3-6 months**	**About a year**	**2-3 years**	**4-5 years**	**I don't remember**
	6.3%	0%	18.8%	12.5%	62.5%
What is your average catch in kg	1-10	11-20	**21-30**	31-40	> 40
	18.6	23.3	9.3	0	50.8
Do you use a storage container onboard	**Yes**		**No**		**Sometimes**
	4.7		95.3		0
Do you take ice onboard?	**Yes**		**No**		
	2.3		97.7		0

Appendix IV Key Quality Gaps in Fish Processing and Transport

Question	Response				
Is your Business Registered	**Yes**			**No**	
	1.4			98.6	
How do you get your raw material?	**Buy from fishermen**		**Buy from my husband**	**Own a vessel**	
	87		11.6	1.4	
Do you receive the product from fishermen on Ice	**Yes**			**No**	
	0			100	
What is your role in the value chain?	**Processors**			**Fishmongers**	
	55.1			44.9	
What do you do with the product?	**Sell fresh**	**Smoke dry**	**Ice and transport to customer**		
	30.4	68.1	1.4		
What Portion (percent) of fish is hot smoked	**All**	**> 50%**	**25-50 %**	**< 25%**	**Non**
	52.2	23.8	4.5	0	19.4
What Portion (percent) of fish is ice chilled?	**All**	**> 50%**	**25-50 %**	**< 25%**	**Non**
	1.9	11.3	11.3	13.3	60.4
Storage temperature of smoked product RT[3] (26-28 ^{0}C)	**Refrigerated**		**Frozen**		**Room**
	0		0		100
How do you transport products to market/consumers or Processing Facility	**Always Iced**		**Always uniced**		**Sometimes Iced**
	21.7		76.8%		1.4
Is facility enclose such that it limits contamination from environmental influences?	**Yes**	**No**	**Somewhat**		**No Facility**
	0	98.6	0		1.4
Are the processes in the facility separated/ partition into high and low risk to avoid cross contamination?	**Yes**	**No**	**Somewhat**		**No Facility**
	0	97.1	0		2.9
Do you have any kind of food safety management system installed in your facility?	**Yes**			**No**	
	4.5			95.5	
Do you document your processes?	**Yes**			**No**	
	0			100	
Have you received any form of training before?	**Yes**			**No**	
	23.2			76.8	
Relevance of training to fish quality and safety	**Yes**			**No**	
	100			0	

[3] Room Temperature

Gender	Females			Males	
	100			0	
Trend of fish	**Smoked**		**Sold fresh**	**Others**	
	68.1		18.8	14.1	
Primary customers	**Local market**			**others**	
	95.7			4.3	
Have you shipped product abroad?	Yes			No	
	15.4			84.6	
Shipping location	**USA**		**West Africa**		**Non**
	13.5		1.9		84.6
How many different shipments have you made?	**Once**	**2-5**	**6-10**	**11-25**	**Non**
	7.1	10.7	3.6	7.1	71.5
Do you have any kind of food safety management system installed in your facility?	**Yes**			**No**	
	4.5			95.5	

Appendix V Consumer Opinion on Fish Quality (at market level)

Question	Response			
Quality preference for fish product	Frozen	Fresh	smoked	
	50.8	48.4	0.8	
Factor influencing choice	**Cheap/affordable**	**Good quality**	**Option available in our local market**	
	13.7	46.8	39.5	
Consumers who eat smoked product	**yes**			**No**
	100			0
Quality rating of smoked product	**Very Good**	**Good**	**Ok/Fair**	
	13.7	71	15.3	
Consumer satisfaction	**Yes**	**Somewhat**	**No**	
	17.7	45.2	37.1	
Related smoke fish issues	Fragmented, broken	Maggot	Mold	Sand
	81.5	1.6	8.9	8.1
Improvement required for smoke fish processing	Reduce fish price only	Reduce fish price and improve quality	Improve fish quality	
	33.9	38.7	27.4	
Consumers' willingness to pay for improvement	Yes	No	Maybe, not sure	
	88.7	0.8	10.5	

Appendix VI Questionnaires

1. Post-Harvest Gap Assessment (Fisherman)
2. Postharvest Gap Assessment (Processor)
3. Market Surveillance of fish Product (Consumer)