*Sustainable Aquatic Research* (2025) 4(1):116-142
https://doi.org/10.5281/zenodo.15255684
e-ISSN: 2822-4140

SUSTAINABLE AQUATIC RESEARCH
www.saquares.com

REVIEW PAPER

# A Review of fish value-added products in Kenya: Current status, challenges and areas for improvement

**Domitila Kyule[1], Jonathan Munguti[1], Mavindu Muthoka[2*], Mary A. Opiyo[1], Jacob Abwao[1], Anne Maundu[3]**

[1]*National Aquaculture Research Development and Training Center (NARDTC), Sagana, Kenya Marine and Fisheries Research Institute (KMFRI), Kenya.*
[2*]*Department of Animal and Fisheries Sciences, Maseno University, Maseno, Kenya.*
[3]*Department of Zoological Sciences, Kenyatta University, P. O. Box 43844 Nairobi, Kenya*

**Citation**

Kyule, D., Munguti, J., Muthoka, M., Opiyo, M., Abwao, J., Maundu. A. (2025). A Review of fish value-added products in Kenya: Current status, challenges and areas for improvement. *Sustainable Aquatic Research, 4*(1), 116-142.

**Article History**

*Received: 08 November 2024*
*Received in revised form:27 March 2025*
*Accepted: 27 March 2025*
*Available online: 30 April 2025*

**Corresponding Author**

*Mavindu Muthoka*

*E-mail: meshackmuthoka98@gmail.com*
*Tel: +254 702838139*

**Keywords**

*Fisheries*
*Aquaculture*
*Value-addition*
*Kenya*

**Handling Editor**

*Sharon Nonato Nuñal*

**Abstract**

Fish products are essential to Kenya's economy and nutrition, yet their high perishability limits their accessibility and export potential. Developing fish value-added products—such as fish samosas, sausages, fillets, and powders—presents a promising solution, potentially enhancing resource utilization, reducing waste, and expanding markets. Despite contributing approximately 0.6% to Kenya's GDP and supporting over 1.2 million livelihoods, the fish sector remains underutilized due to limited value addition. This review provides the first comprehensive synthesis of Kenya's fish value-added sector—bridging fragmented insights on product types, technologies, economic potential, and policy gaps—offering a practical foundation for informed decision-making and investment. Key products included in this review are samosas, fillets, sausages, fish balls, smoked fish, fish oils, burgers, and soups, alongside primary processing techniques such as improved smoking kilns, Mama Karanga boxes, chilling, and freezing. The review followed the PRISMA framework to systematically identify, screen, and analyze relevant peer-reviewed articles, grey literature, and government reports. Out of 625 initially identified documents, 64 high-quality sources were included in the final synthesis. Results show that value-added products such as fish fingers, sausages, and samosas are increasingly preferred due to their profitability, consumer appeal, and potential to reduce post-harvest losses. However, their development is hindered by weak market linkages, poor regulatory and quality controls, limited access to technology, inadequate policy support, and limited awareness among consumers and producers. Increasing consumer and producer awareness through training, improved market information systems, and accessible financing options could stimulate growth of the fish value addition sector. This paper's insights underscore the need for strategic interventions to unlock the potential of Kenya's fish value-added sector, fostering livelihood enhancement and food security. Implementation of targeted programs and policies can transform the fisheries and aquaculture sector into a robust contributor to the country's economic resilience and community well-being.

## Introduction

Globally, the fish consumption rate is growing faster than the global population due to the awareness of the health benefits of consuming fish, increased incomes, and rising urbanization (Issifu et al., 2022). Fish and fishery products are critical for nutrition and food security and play a vital role in the economy of many countries, particularly those in the developing world (FAO, 2020). Fish has been recognized to contain polyunsaturated fatty acids, protein (rich in essential amino acids), and other nutrients that contribute positively to good health (Khalili & Sampels, 2018). Many of these beneficial micronutrients are generally more abundant in aquatic animals and plants than in meat or terrestrial vegetables. Also, fish enzymes have applications in many other industries, and many nutraceuticals from fish have enormous applications in human health. Fish consumption also contributes immensely to heart health and proper growth and development in children. Fish is recommended to be consumed more after certain ages for the superior alternative benefits they provide (Rondanelli et al., 2020). Value-added products, such as fish oils and nutraceuticals, can further amplify these health benefits, providing a convenient and nutritious food option (Peñarubia et al., 2023).

In Kenya, the demand for aquaculture products is increasing due to the rapid population growth and the declining catches from capture fisheries (Nyawade et al., 2021). The fisheries sub-sector comprises marine, inland fisheries and aquaculture. The main freshwater species are Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Omena (*Rastrineobola argentia*), Nile perch (*Lates niloticus*), and Nile carps (*Labeo niloticus*). Tilapia and African catfish are the main cultured species in the country, with the supply of other species from inland capture fisheries (Kyule et al., 2016). Owing to their high perishability and shorter life, Kenyan fresh fish availability as animal-sourced protein food is threatened and is of little significance to international trade. This inefficiency is a critical issue that undermines the sustainability and profitability of the fish industry. Further, micronutrient deficiencies affect hundreds of millions in the world, particularly women and children in Kenya, leading to increased risks of prenatal and maternal mortality, growth retardation, child mortality, cognitive deficits, and reduced immune function (Lokuruka, 2020). As a result, there is a need for superior farmed fish products that meet consumer preferences.

One potential solution to these challenges is the development and commercialization of fish value-added products, which can enhance the utilization of fish and fishery products, reduce waste, create new market opportunities, and improve community livelihoods (Magesa et al., 2024). The Kenyan fisheries and aquaculture industry contributes approximately 0.6% to the GDP (KNBS, 2024). It has been argued that fisheries' contribution to GDP could be higher if value addition along the supply chain and interventions against post-harvest losses are promoted (Muma, 2015). Value-added products are usually perceived to have added ingredients such as a coating or sauce, are prepared, trimmed, or provide more convenience to the user. Value combines quality, service, and price (Binsi & Parvathy, 2021).

In the context of the fish industry, value-added products can include a wide range of items such as ready-to-eat meals, smoked and dried fish, fish fillets, fish oils, and nutraceuticals (Abiodun-Solanke, 2020). These products can cater to diverse consumer preferences, offer convenience, and provide functional benefits, adding significant value to the original raw fish. The development of fish value-added products is not only a means to improve profitability for producers but also a strategy to utilize low-value fish species in a better way to meet the growing demand for high-quality, convenient, and nutritious food options (Mehta et al., 2023). Omega (2023) reported that a substantial portion of fish catches are either discarded or processed inefficiently, leading to economic losses and environmental degradation. Therefore, the fish value-added product sector holds immense potential for addressing some of the critical challenges faced by the fishing industry in Kenya. By enhancing the value of fish products, reducing waste, and creating new market opportunities, this sector can contribute to the sustainability and profitability of the fish industry (Stevens et al., 2018).

Despite the critical role of value addition in enhancing the fish industry's sustainability and profitability, the current status, challenges, and opportunities of fish value-added products have not been comprehensively documented. This lack of comprehensive documentation hinders the industry's ability to fully leverage on the potential of value-added products to address critical issues such as resource inefficiency, waste, and market access. The absence of detailed information on the development, processing technologies, market dynamics, and regulatory frameworks of fish value-added products creates a significant knowledge gap that needs to be addressed to drive innovation and growth in this sector.

This review provides a detailed and comprehensive analysis of the fish value-added product sector's current status, challenges, and areas for improvement. This review provides valuable insights that can guide policy decisions and the allocation of resources to support the growth of value-added fish products. For producers, processors, and marketers, understanding the current trends and challenges in the value-added product sector is crucial for making informed business decisions. Additionally, this review can increase consumer awareness and demand for these products by highlighting the benefits and availability of fish value-added products. This, in turn, can drive market growth and support the industry's overall sustainability goals (Stevens et al., 2018).

## Materials and Methods

The methodology followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Figure 1; Page & Moher, 2017), which supports transparency and replicability. An exhaustive literature search was conducted in August 2024 across multiple electronic databases, including Google Scholar, ScienceDirect, PubMed, and the Aquatic Sciences and Fisheries Abstracts (ASFA). The search targeted peer-reviewed articles, government and institutional reports, and grey literature relevant to Kenya's fish value-added products. Search terms were constructed to include "fish value-added products in Kenya," "fish processing challenges in Kenya," "Kenya fisheries sector," and "aquaculture product development." Boolean operators (AND, OR) were employed to refine the results and capture a broad range of relevant studies.

The initial search yielded a total of 625 articles, which then underwent a thorough screening process to ensure alignment with the study's objectives. The initial screening removed 230 duplicates, resulting in 395 unique studies. Titles and abstracts of these studies were reviewed against the inclusion and exclusion criteria. Studies were included if they specifically addressed fish value-added products, fish processing methods, or challenges in the Kenyan context. Only articles in English and accessible in full-text were considered to maintain consistency and reliability across data sources. Conversely, studies focusing solely on fisheries outside Kenya, articles not directly relevant to fish value addition (such as those focused on general aquaculture or unrelated food products), and studies without empirical data were excluded. Following this title and abstract screening, 198 articles were selected for a full-text review. In this stage, each article was evaluated by two independent reviewers to confirm relevance and adherence to the review's scope, leading to a final selection of 42 articles. Any disagreements between reviewers were resolved through discussion or by consulting a third reviewer, reducing selection bias and ensuring accuracy in the final dataset.

To ensure consistency and rigor, a structured data extraction form was developed to systematically capture essential information from each study. Data points included the study's authors, year of publication, study design, objectives, types of fish value-added products, processing methods, reported challenges, and suggested improvements. The extraction process was performed independently by two reviewers to maintain consistency, with cross-validation to ensure reliability. Quality assessment was conducted using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018), which evaluates each study on methodological soundness, relevance, and rigor. This tool provided a standardized assessment framework suitable for diverse study types, including qualitative, quantitative, and mixed-method studies. Studies were rated on clarity of research questions, appropriateness of study design, and

validity of findings. Out of the 82 full-text articles, 64 met the MMAT quality threshold, with a score of 75% or higher, and were thus included in the synthesis, ensuring that only high-quality data contributed to the review findings.

Data synthesis was achieved through a thematic analysis approach, where extracted data were organized into key themes: types of fish value-added products, processing techniques, and technologies, challenges faced by the sector, and potential strategies for improvement. This thematic framework enabled the identification of cross-cutting issues and emerging trends that affect the fish value-added sector in Kenya. Data from selected studies were triangulated with grey literature, industry reports, and government publications to provide a comprehensive, multi-dimensional perspective.

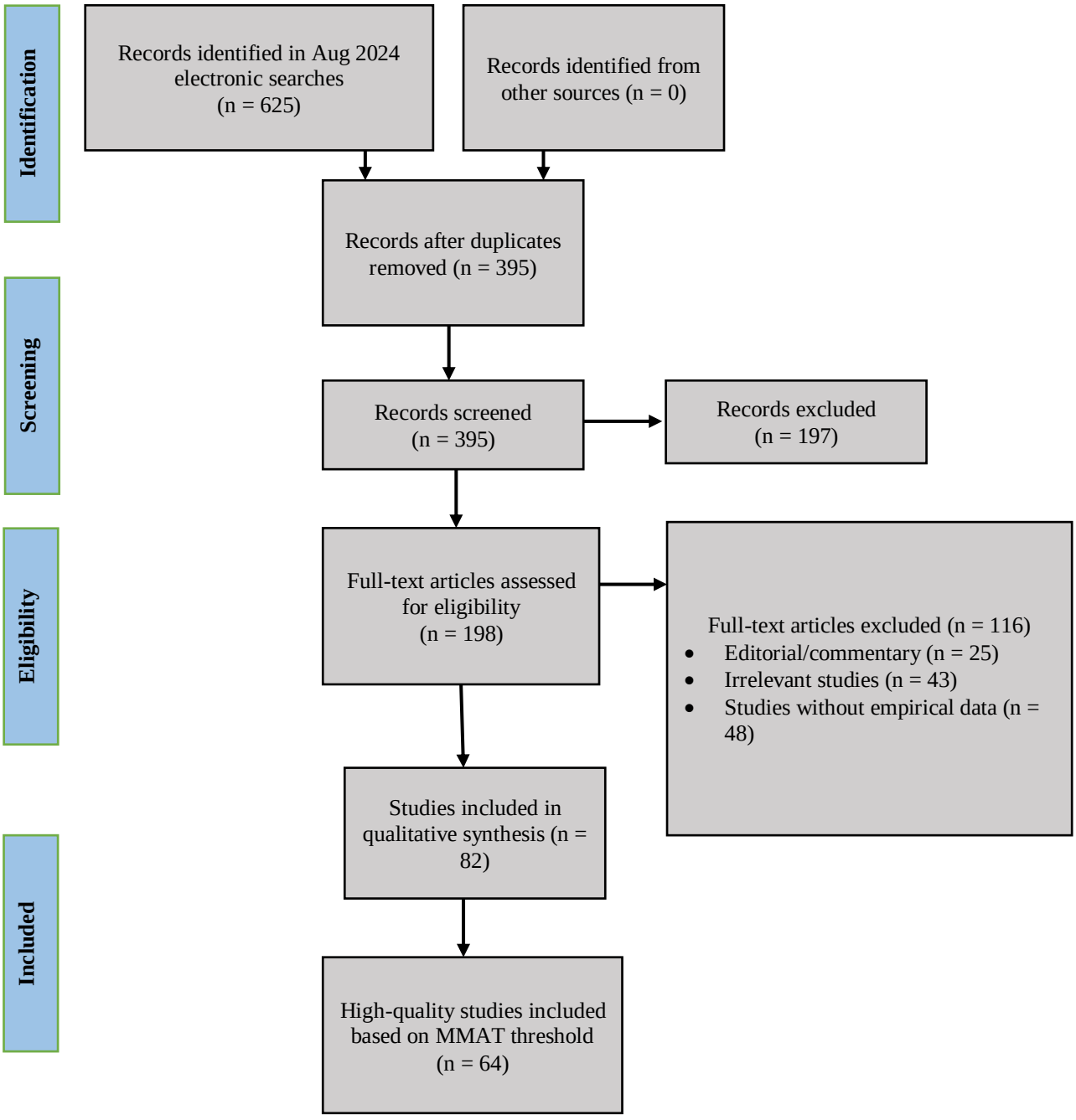


**Figure 1.** Flow diagram of identification, screening, and inclusion of studies for the review.

## Results

### *Current state of fish value-added fish products available in Kenya*

### *Fish samosas*

Fish samosas are a popular value-added fish product in Kenya (Figure 2), widely enjoyed for their unique blend of flavors and nutritional benefits. They are crafted from minced fish and finely chopped onions, ginger-garlic paste, chili powder, black pepper powder, and garam masala. The samosa pastry and cones are made using plain wheat flour, cold water, and salt (Kyule et al., 2014). Fish samosas have gained traction in Kenya due to their versatility and appeal across consumer groups. This value-added product enhances the economic value of fish and provides an avenue for culinary innovation and cultural integration in Kenyan cuisine. The rising popularity of fish samosas can be attributed to their convenience, taste, and the nutritional benefits associated with fish, which is a good source of protein, omega-3 fatty acids, and essential nutrients.

**Figure 2.** Typical appearance of fish samosa (Kyule-Muendo et al., 2021).

Producing fish samosas contributes to food security and nutrition, providing a tasty alternative to traditional fish dishes. The ability to incorporate various spices and ingredients enhances the flavor. It caters to diverse palates, making fish samosas a favored snack or meal option across different demographic segments in Kenya. Nyamwaka et al. (2020) noted that fish samosa are considered a source of high-quality animal protein available both in urban and rural areas for human consumption in Kenya. Further, developing value-added products like fish samosas has helped reduce post-harvest losses and created new market opportunities for fish farmers and processors. This has been particularly beneficial in regions around Lake Victoria, where fish processing and trade are vital to the local economy (Kimani et al., 2022). In a study conducted by Kyule et al. (2016; 2020), fish samosas were the most preferred fish valued-added product in various counties in Kenya due to their delicious taste compared to other products.

### *Fish sausages*

Fish sausages (Figure 3) are typically made by combining minced fish with various spices and binders and encasing the mixture in a natural or synthetic casing before cooking (Ninan, 2021). The primary ingredient, minced fish, provides a high-quality source of protein, omega-3 fatty acids, and essential nutrients vital for a healthy diet (Danilyuk et al., 2024). Making fish sausages involves several steps, including selecting fish, mincing, mixing with spices and binders, stuffing into casings, and cooking by steaming, boiling, or grilling.

Fish sausage offers a nutritious alternative to traditional meat sausages, catering to the growing health-conscious population segment in Kenya. Fish sausages are lower in fat and calories than their meat counterparts, making them an attractive option for consumers looking to maintain a healthy lifestyle. Moreover, using locally sourced fish to produce these sausages supports the local fishing industry and promotes sustainable fishing practices. This enhances the economic value of fish and helps reduce post-harvest losses, a significant challenge in the Kenyan fish industry (Odoli et al., 2019).

**Figure 3.** Typical appearance of fish sausages (Courtesy of Dr. Domitila Kyule, KMFRI Sagana)

Fish sausages can be flavored in various ways, allowing for various product variations that cater to different taste preferences (Nkrumah, 2015). This diversity in flavors and preparations makes fish sausages a versatile product that can be enjoyed as a snack, a meal component, or in various culinary applications. The production of fish sausages also aligns with the broader trend of value addition in the Kenyan food industry. By transforming raw fish into a ready-to-eat product, manufacturers can extend the shelf life of fish and create new market opportunities. This value-addition process is essential in addressing food security challenges, as it ensures that fish products remain available and accessible to consumers over a more extended period (Ninan, 2018).

In recent years, there has been a noticeable increase in the number of small and medium-sized enterprises (SMEs) involved in the production of fish sausages in Kenya (Wairimu, 2020). These businesses play a crucial role in driving innovation and providing employment opportunities in the local economy. The growth of SMEs in this sector is supported by various initiatives aimed at enhancing the capacity of fish processors through training and access to modern processing technologies (Hasan et al., 2020). These efforts are vital in ensuring that the quality and safety standards of fish sausages are maintained, thereby boosting consumer confidence and market acceptance.

### *Fish Fingers*

Fish fingers (Figure 4) have emerged as a popular value-added fish product in Kenya, gaining significant traction due to their convenience, taste, and nutritional benefits. Made by coating strips of fish fillets with breadcrumbs and then deep-frying or baking them, fish fingers are appreciated for their crispy texture and appealing flavor. According to Kyule et al. (2014), fish fingers were second in preference only to samosas in several study areas in Kenya, highlighting their wide acceptance among consumers. This preference is primarily driven by fish fingers' palatability, making them a favored choice among children and adults. Additionally, including catfish in the production of fish fingers diversifies the product range and enhances traders' profitability. Kyule et al. (2014) also reported that traders could achieve a 100% profit margin above the total cost by incorporating catfish fingers, indicating a lucrative market potential.

**Figure 4.** Typical appearance of fish fingers (Courtesy of Dr. Domitila Kyule, KMFRI Sagana)

Fish fingers address the growing demand for quick and easy meal options in urban areas by transforming raw fish into convenient, ready-to-eat products. This trend supports the local fish industry by creating new market opportunities and reducing post-harvest losses (Binsi & Parvathy, 2019). Furthermore, the production of fish fingers aligns with health-conscious consumer preferences, as they offer a low-fat, high-protein alternative to traditional meat products. Studies

have shown that value-added fish products like fish fingers contribute significantly to the economic sustainability of the fish sector in Kenya, providing employment opportunities and supporting livelihoods in fishing communities (Kyule et al., 2014).

### *Fish fillets*

Fish fillets (Figure 5) are among Kenya's most prominent value-added fish products, offering a versatile and convenient option for consumers seeking high-quality protein. These products involve removing the bones from the fish and slicing the flesh into clean, ready-to-cook pieces (Ninan, 2022). The process not only enhances the usability of the fish but also increases its market value by catering to the demand for boneless, easy-to-prepare fish products. Fish fillets are particularly popular in urban areas where busy lifestyles drive the preference for quick and healthy meal options. In Kenya, fish fillets are primarily derived from species like Nile perch and tilapia, which are abundant in Lake Victoria. The production and marketing of fish fillets have provided significant economic benefits, particularly for small-scale fish processors and traders, by creating employment opportunities and boosting local economies (Ayuya et al., 2021).

**Figure 5.** Typical appearance of fish fillet (Courtesy of Dr. Domitila Kyule, KMFRI Sagana)

Studies have shown that the fish fillet industry in Kenya has been expanding, with innovations in processing and packaging contributing to better product quality and shelf life. Kenya is a leading exporter of fresh and frozen fish fillets in East Africa. In 2022, fish fillets and other fish meat made up 0.216% of Kenya's total exports, which was an increase from 2021's 0.182%. The main destinations for Kenya's fish fillet exports in 2022 were the Netherlands ($3.55 million), Italy ($2.1 million), Israel ($1.65 million), Romania ($1.4 million), and Spain ($1.35 million) (Trend Economy, 2024) (Figure 6).

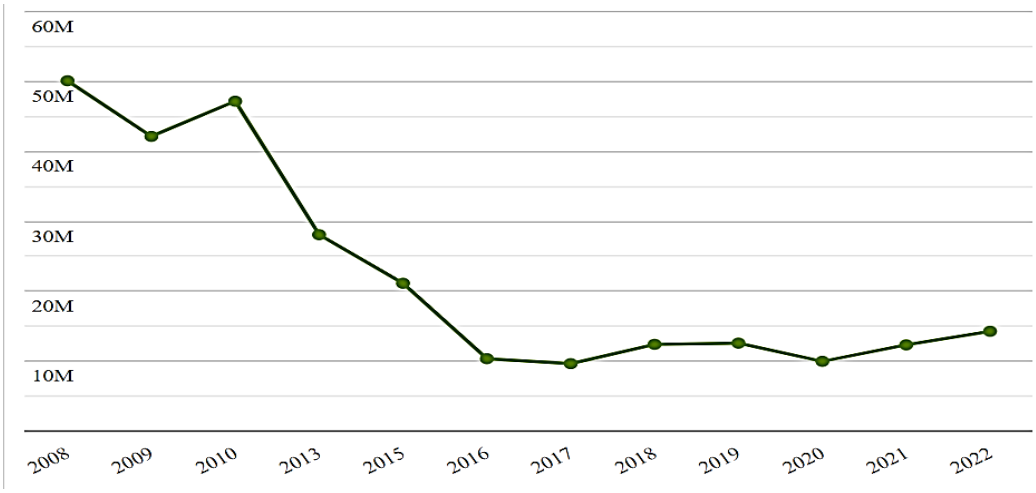


**Figure 6.** The value of exports of fish fillets and other fish meat (whether or not minced), fresh, chilled, or frozen from 2008 to 2022 (Trend Economy, 2024).

### *Fish balls*

Fish balls are a popular value-added fish product in Kenya, made from minced fish fillet mixed with seasonings and binders (Kyule et al., 2016). Fish balls are shaped into small, round portions and then cooked by boiling, steaming, or frying (Figure 7). This product is particularly favored for its ease of preparation and the ability to incorporate a variety of fish species (Herdiana & Widaputri, 2022), including tilapia and Nile perch, which are abundant in Kenya's lakes and rivers. The popularity of fish balls is evident in

both local markets and urban centers, where busy lifestyles drive the demand for quick and healthy meal options. Recent studies have shown that Kenyan consumers are increasingly embracing fish balls due to their taste and nutritional value, providing a significant source of protein, omega-3 fatty acids, and essential vitamins and minerals (Kyule et al., 2020). The current state of fish balls in Kenya reflects a growing industry with substantial economic potential. Small-scale processors and entrepreneurs have capitalized on the rising demand, creating employment opportunities and supporting local economies. The production of fish balls also plays a crucial role in reducing post-harvest losses by transforming less marketable fish into valuable products, thereby enhancing food security.

**Figure 7.** Typical appearance of fish balls (Courtesy of Dr. Mary Opiyo, KMFRI Sagana)

### *Smoked fish (Catfish and tilapia)*

Smoked fish, particularly catfish and tilapia, is a prominent value-added product in Kenya, reflecting both traditional culinary practices and modern market demands (Kyule et al., 2014). This method of fish preservation involves curing the fish with smoke, which not only imparts a distinctive flavor but also significantly extends its shelf life by reducing moisture content and inhibiting bacterial growth (Barros et al., 2023). The process typically involves cleaning and gutting the fish, salting or marinating it, and then smoking it over low heat for several hours. This technique is especially valuable in regions with limited access to refrigeration, providing a practical solution for preserving fish and ensuring food security. Though they are one of the least preferred value added products, smoked catfish and tilapia are popular in both rural and urban markets across Kenya, catering to a wide range of consumers who appreciate the convenience and rich taste of smoked fish (Obiero et al., 2014). Small-scale fish processors and traders have benefited from adopting improved smoking technologies that enhance product quality and safety ((Kyule-Muendo et al., 2021).

Kyule et al. (2014) reported that traders in Kirinyanga and Meru counties have been specializing in deep-fried catfish for their livelihood which they claimed was a good business and they further reported an increase in profit and the number of consumers after introducing the diversified products into the market hence an increase in the number of people consuming fish

### *Dried tilapia*

Dried tilapia, locally known as Obambo in the Lake Victoria region, is a significant value-added fish product in Kenya, particularly cherished for its long shelf life and distinctive flavor (Theuri et al., 2014). The traditional drying process involves cleaning and gutting the tilapia, followed by salting, sun-drying, or smoking to reduce moisture content and prevent spoilage. This method is especially advantageous in areas with limited access to refrigeration, allowing fish to be stored for extended periods without the risk of spoilage (Odour-Odote, 2020). Dried fish is a staple in local diets and a vital source of income for fishing communities, who can sell the fish in local and regional markets. The demand for the value added fish has remained robust due to its versatility in cooking and its ability to retain nutritional value, including high levels of protein and essential minerals (Banna et al., 2022). Innovations in drying techniques, such as solar dryers, have been introduced to improve efficiency and hygiene, resulting in a better-quality product that meets food safety standards (Ochieng et al., 2015).

### *Fish oil*

Fish oil is a notable value-added fish product in Kenya, renowned for its extensive health benefits and economic potential. Derived primarily from species like Nile perch, fish oil is rich in omega-3 fatty acids, vitamins A and D, and essential nutrients that support cardiovascular health, brain

function, and overall wellness (Mwanja & Munguti, 2010; Aloo, 2014). The extraction process typically involves using modern techniques such as wet pressing (WP), cold extraction, enzymatic extraction, and supercritical fluid extraction (SFE) (Eshari et al., 2022) to ensure the purity and quality of the oil, making it suitable for both human consumption and industrial applications. In Kenya, fish oil production has gained traction as a means to maximize the utilization of fish by-products, thereby reducing waste and enhancing the profitability of the fish processing industry (Patrick, 2021). The growing awareness of the health benefits associated with omega-3 fatty acids has spurred demand for fish oil supplements, contributing to a burgeoning market locally and internationally (Opiyo et al., 2018).

***Fish burgers***

Fish burgers are typically made from minced fish such as tilapia or Nile perch (Figure 8). They are mixed with various seasonings and binders before being shaped into patties and cooked (Lithi et al., 2020). These burgers offer a healthy alternative to traditional beef or chicken burgers, providing high levels of protein, omega-3 fatty acids, and essential nutrients while lowering fat and calories (Iman et al., 2024). The popularity of fish burgers is particularly evident in urban areas where busy lifestyles drive the need for quick, ready-to-eat meals that do not compromise nutritional value. Recent studies indicate that consumers appreciate fish burgers' taste and health benefits, contributing to their rising market presence (Paci et al., 2018).

**Figure 8**. Typical appearance of fish burgers (Courtesy of Dr. Domitila Kyule, KMFRI Sagana).

***Fish soup***

Fish soup is a valued and traditional value-added product that typically includes fish such as tilapia or Nile perch, combined with a variety of local vegetables, spices, and herbs to create a hearty and nutritious meal (Van Der Knaap & Maxillion, 2006). Fish soup is particularly popular in coastal and lake regions, where fresh fish is abundant. It offers a significant source of protein, omega-3 fatty acids, vitamins, and minerals, making it an essential part of the diet for many Kenyan households (Duru et al., 2009). The preparation of fish soup varies across regions, reflecting diverse culinary traditions and preferences. In recent years, there has been a notable increase in the commercialization of fish soup, with packaged and ready-to-eat versions becoming available in urban markets, catering to busy consumers seeking convenient yet healthy food options.

***Nutrition-based value-added products, e.g. Fish powders for infants, "Boneless fish supplements***

Small-sized fish, usually not very marketable but produced on a large scale, can be dried and crushed into powder and made available (Obiero et al., 2019). Fish powder is high in protein and contains many essential micronutrients even after four months of storage (Sroy et al., 2023). According to the 2014 Kenya Demographic and Health Survey, the national prevalence of stunting was 26%, underweight at 11%, and wasting was estimated at 4%, which leads to cognitive and physical damage. Findings show that chances of such children recovering decreased after they reached two years. In Kilifi, for example, one out of five children under five years old are underweight and stunted due to chronic nutritional deficiency (Cheruiyot et al., 2022). Stunting is being severely short for one's age. It is an irreversible consequence of poor maternal diet, poor hygiene and sanitation practices, and an inadequate diet during the first two years of a child's life. Stunting undermines children's health through increased illness. It also impacts children's educational achievement by limiting cognitive development and years of schooling and reducing lifetime earnings (Ekholuenetale et al., 2020).

### *Overview of the technologies and methods used for processing and fish value-addition*

#### *Smoking*

Most fishermen and a few farmers apply this technique using traditional smoking kilns (Ngaruiya, 2021). The most commonly used fuel is wood, free from timber preservatives, paint, gum, or any other added substances. The fish is exposed to temperatures of 70 ℃.

#### *Improved Fish Smoking Kiln*

Traditional kilns had significant limitations, such as low capacity and inefficient use of firewood, which exacerbated deforestation. Additionally, the smoke produced posed health risks, affecting the eyes and lungs of operators, and the direct heat exposure often led to burns on their fingers, making the process very labor-intensive. Users also experienced poor-quality smoked fish prone to mold due to ineffective smoking techniques. These challenges highlighted the need to develop various models of improved ovens and kilns to utilize different fish species more effectively and efficiently in order to address the shortcomings of traditional kilns and enhance performance (Obiero et al., 2019).

The enhanced smoking kiln is constructed using readily available materials (Figure 9). It features a rectangular design with an inner lining of stainless steel. This stainless-steel sheet is insulated with fiberglass and coated with an additional stainless-steel layer. The double-wall construction with insulating material helps conserve heat energy by reducing heat loss, ensuring a comfortable working environment, and improving the kiln's overall efficiency. The kiln includes four shelves with six trays made of stainless wire gauge and fine wire mesh edges to prevent dried fish from falling through. These trays can be pulled out smoothly without tilting. The fish drying capacity varies depending on the species and thickness. The kiln also has a double-wing door that opens and closes easily, enhancing air and heat circulation within the chamber and effectively removing moisture from the dried product. A chimney at the top of the kiln serves as an outlet for moisture-laden air. For smoking and drying, the kiln can use sawdust, charcoal, or firewood (Ogello et al., 2023).

**Figure 9.** Improved fish smoking kiln (courtesy of Dr. Domitila Kyule of KMFRI, Sagana)

#### *Mama Karanga Box*

Mama Karanga refers to female small-scale fishery actors: traditional fishmongers and processors, well-known for their characteristic fried fish sold in the street markets of coastal Kenya. Their fish is mainly used at the household level. The improved fried fish display box comes with a solar lantern that runs for six hours on a high setting and 15 hours on a low setting and can be put out in the sun to charge during the day. The box can hold 10 to 15 kg of fish and is lined with aluminium instead of the newspapers that line traditional boxes. It is also well-ventilated and easy to clean, thereby boosting food safety and hygiene.

#### *Chilling and freezing*

To increase fish's shelf life, the technology of chilling at between 7°C and 16°C and freezing at -18°C has been used (Figure 10). Freezing is the most commonly used method.

**Figure 10.** Fish in a freezer (courtesy of Dr. Domitila Kyule of KMFRI, Sagana)

Sun-drying is practiced in northern and coastal Kenya, where the climatic conditions are hot in nature. Others employ slow refrigeration where the fishermen and farmers store fresh fish in ice boxes with ice blocks for 2 to 3 days. Additionally, there is the combined technology for Solar-wind dryers. For instance, Vanga and Kipini at the coast employ a solar-wind dryer and most traders practice drip drying before deep frying.

## Economic analysis of some of the value-added products

An economic analysis involves the determination of the prevailing economic conditions, which is essential to the survival of the business. It's a method of arriving at a decision that involves a comparison of a detailed analysis of costs and of the expected benefits. This guides the investor to determine the selling price of the products to be assured of the business making profits. Besides, the investor would be able to decide on the value-added products to concentrate on, considering the margin and demand of products by his consumers.

This analysis helps the investor to a great extent in knowing whether he is in profit or loss. Cost-benefit analysis is one of the best types of economic analysis; it uses monetary terms and tries to determine if the business is gaining or losing. It helps a user adjust ingredients to get the most profit used in formulating the recipes to prepare value-added products (Kyule-Muendo, 2017). Any benefit that arises from the effort is measured against its cost in a cost-benefit analysis. Value addition is any activity that tends to make the product increase its value such that the investor earns better profits. Apart from extending the shelf life of fish, thus preventing unwarranted losses incurred due to spoilage, there is an increase in consumption as more varieties come to the market. Table 1 below provides the costing and percentage profit summary for the fish value-added products (Kyule-Muendo, 2017).

**Table 1.** Costing and percentage profit for fish value-added products (adapted from Kyule-Muendo, 2017).

| Production type | Cost of production/piece (KES) | Selling price/ Piece (KES) | Profit/piece (KES) | % profit |
|---|---|---|---|---|
| Catfish samosa | 32 | 40 | 8 | 25 |
| Fish finger | 15 | 30 | 15 | 100 |
| Fishball | 28 | 30 | 2 | 7 |
| Deep fried catfish | 50 | 100 | 50 | 100 |
| Smoked catfish | 130 | 200 | 70 | 54 |
| Fish burger | 150 | 200 | 50 | 33 |
| Fish pie | 150 | 200 | 50 | 33 |
| Fish sausage | 18 | 30 | 12 | 67 |
| Fish soup | 10 | 20 | 10 | 100 |
| Fish skewer | 20 | 50 | 30 | 100 |

### *Challenges facing the fish Value-addition Subsector*

#### *Regulatory and quality control*

For retailers, value addition is limited by the enforcement of standards for product handling, development, differentiation, and packaging to satisfy customer preferences. The retailer is the end point from where human consumers buy the product. While standards for food handling and safety exist, they are often not adequately enforced by stakeholders, leading to unmet consumer demands. For example, hazard analysis and critical control point (HACCP) protocols are not widely implemented for most fish species like Omena, such that not all retailers are aware of the bare minimum or maximum temperature levels, durations over which the product is to be stored, shelf life, and handling to ensure food safety and quality. In rural markets, for example, Omena is not packaged, and hygiene safety is not guaranteed. Therefore, any value addition undertaken earlier is compromised by exposure to dust and dampness to which the product is subjected (Owaga et al., 2009).

Maina (2011) analyzed the performance of the Omena market in Kisumu, Nakuru, and Nairobi and found a lack of standardization of the product for human or industrial processing. This suggests constraints to value addition when raw materials or products are not standardized. The study also found only basic value-addition activities regarding drying, storage, and sorting (removing impurities) performed mainly by small-scale processors and wholesalers, save for industrial processing of Omena. Manyala and Adoyo (2011) analyzed the demand and supply for high-quality Omena value chain in Kisumu, Nakuru, Eldoret, and Nairobi among fishermen, processors, wholesalers, retailers, and consumers through primary data collection, a survey, and stakeholder validation. The study found challenges related to the lack of enforcement of standards for grading and processing Omena for human and animal feed, as well as the lack of proven processing technology, among other challenges in the value chain.

Another example of a lack of enforcement of standards for the product concerns different packaged products in smaller and more significant weight units at supermarkets with varying tags of price (Muma, 2015). First, consumers cannot be guaranteed about the shelf life and food safety of the packaged product since the shelf life is not marked on the packets. Second, smaller units are costly, while larger packaged units are less costly. This will affect demand, yet the packaging and pricing of the different weights (packaged) are not based on market research on consumer preferences. This, therefore, affects value addition through demand (Roheim et al., 2007).

#### *Lack of access to capital and technology*

Lack of access to capital and technology in Kenya manifests in several ways, including limited modernization of processing facilities, inadequate technological advancements, and restricted financial support for small and medium-sized enterprises (SMEs) engaged in the fish value-addition sector (Mahmud et al., 2020). Access to capital is critical for the growth and sustainability of value-added fish processing. However, many SMEs in Kenya struggle to secure the necessary funding to invest in modern processing equipment and technologies. This financial constraint limits their ability to produce high-quality, value-added fish products that meet international standards (Ogello et al., 2023). The high cost of borrowing due to high interest rates, stringent collateral requirements, and limited availability of financial products tailored for the fisheries sector exacerbate this problem. Consequently, many fish processors rely on outdated and inefficient technologies, which hampers productivity and reduces the competitiveness of Kenyan fish products in both local and international markets.

Technological advancement is another critical area where the fish value-addition sector in Kenya lags behind. Advanced technologies in processing, packaging, and preservation can significantly enhance the quality and shelf-life of fish products. However, adopting such technologies is often hindered by the high initial investment costs and the lack of technical expertise (Theuri, 2015). Many fish processors in Kenya cannot access modern processing equipment such as automated filleting machines, vacuum packaging systems, and advanced refrigeration units. This technological gap affects the quality of the products and limits the range of

value-added products that can be offered to the market (Theuri, 2015).

Several studies have underscored the profound impact of these challenges on Kenya's fish value-addition sector. For example, Kimani et al. (2020) revealed that financial capital is the most significant constraint hindering sector growth, as reported by fish processors during their analysis of constraints and opportunities in marine small-scale fisheries along the Kenyan coast. The same study also highlighted the critical absence of modernized equipment, noting that an efficient cold chain is essential for providing ice to fishing vessels and for storage during fish gluts. This deficiency in financial and technological resources severely limits the capacity of fish processors to enhance productivity, maintain quality, and expand market reach, thereby stifling the sector's potential for growth and development.

***Lack of infrastructure***

One of the foremost challenges facing the value addition of fish products in Kenya is the lack of or limited infrastructure. This constraint significantly hampers the growth and development of the fish industry, which is vital for enhancing food security, creating employment, and boosting the economy. The infrastructure necessary for the fish value chain includes adequate facilities for landing, storage, processing, and transportation. In many parts of Kenya, these facilities are either non-existent or inadequately maintained, leading to substantial post-harvest losses. For instance, a study by Njiru et al. (2008) highlighted that a high percentage of fish harvested in Lake Victoria is lost due to poor handling and inadequate preservation facilities. This loss is a direct consequence of insufficient cold storage and ice production facilities which are essential for maintaining the quality of fish from the point of capture to the market (Theuri, 2015). Moreover, the absence of efficient transportation networks further exacerbates the problem. Fish must be transported over long distances to reach processing facilities or markets, often under suboptimal conditions. This results in the deterioration of fish quality and significant economic losses for fishermen and traders. A study by Syanya et al. (2024) pointed out that the poor state of roads around Lake Victoria makes it challenging to transport fish quickly and safely, leading to delays that affect the freshness and market value of the fish.

Processing facilities are another critical aspect where infrastructural inadequacies hinder fish value addition. In Kenya, most fish processing plants are concentrated in urban areas, far from the main fishing grounds (Wamukota, 2009). This geographic disparity means fishermen have limited access to processing facilities, reducing their ability to produce value-added products such as fillets, smoked fish, and fish meal. A study by Theuri (2015) emphasized that the lack of nearby processing facilities forces many fishermen to sell their catch in raw form at lower prices, thus missing out on potential higher earnings from value-added products. Mahmud et al. (2020), in a study on the Kenyan coast, also reported the freezer/fridge/chiller is the dominant equipment owned by the fish traders; as such, the opportunities to engage in scale fish value addition are limited. This is because fish value addition requires investment in equipment and tools for cutting, frying, filleting, packaging, etc. It is therefore imperative that the fish traders invest in more equipment to upscale value addition activities.

Additionally, the lack of infrastructure constricts market access for value-added fish products. Modern market facilities with cold storage and hygienic conditions are scarce, which limits the distribution and retail of processed fish products (Alliance, 2016). This infrastructure gap not only affects domestic sales but also limits the potential for export, as international markets demand stringent quality standards that require advanced processing and storage facilities. Odoli et al. (2019) highlighted the need for investment in infrastructure to support the sustainable growth of the fish fillet industry. A study conducted by Mwirigi & Theuri (2012) regarding the challenge associated with the value addition of the seafood value chain on the northern coast of Kenya found that there are inadequate facilities to undertake value addition.

***Lack of research and innovation***

Research and innovation is critical in the fish value-addition sector in Kenya. Lack of research and innovation hampers the development of

effective strategies to address various issues within the sector. Limited research leads to an inadequate understanding of market trends, consumer preferences, and the best practices in processing and preservation techniques, which are vital for producing competitive value-added fish products (Theuri, 2015). One of the studies highlighting this challenge is by Obiero et al. (2014), which examined consumer preferences and marketing of farmed Nile Tilapia and African Catfish in Kirinyaga and Vihiga Counties. The study underscored the need for targeted research to understand consumer behavior better and to develop marketing strategies that align with these preferences (Obiero et al., 2014). This gap in consumer-focused research indicates a broader issue of insufficient market research, which is necessary to tailor products that meet specific consumer demands and enhance market penetration.

In addition, Esilaba et al. (2017) conducted a study on urban consumers' fish preferences in Nakuru Town, revealing key determinants influencing fish selection, such as price, convenience, safety concerns, and consumer experience. The study suggests that introducing fish labeling and enhancing convenience traits like filleting could potentially increase fish consumption. However, the lack of comprehensive research on these determinants means that many processors are not fully aware of how to adjust their products to meet market demands effectively (Esilaba et al., 2017).

Further, the factors that affect value addition through packaging, storage, and transportation of the product are not controlled for because stakeholders in the fishery sub-sector have not agreed on specifications of the conditions that influence the biophysical integrity and food safety of the products under transportation. For example, the fumigation of the transport facility, the handling of the product, and the methods for stacking bags could affect the quality of the product (Ninan, 2021). The main factor behind this problem is the lack of basic and applied research knowledge in Kenya regarding food safety and sanitary requirements for transportation of fish. There are no guidelines available regarding how fish should be compacted and stacked to allow aeration of the product and avoid risks to food safety (Ninan, 2021).

***Lack of policy and legal framework***

The lack of a robust policy and legal system is a big challenge that hampers the development of fish value-added products in Kenya. This deficiency manifests in various ways, including inadequate regulatory support, inconsistent and conflicting policies, and insufficient enforcement of existing regulations (Akullo, 2023), all of which create an uncertain environment for stakeholders in the fish value-addition sector. One of the critical issues is the inconsistency and lack of clarity in the regulatory framework governing fish processing and value addition (Theuri, 2015). Policies related to food safety, quality standards, and export requirements are often fragmented and poorly enforced, leading to significant challenges for processors trying to comply with international standards. For instance, Henson et al. (2000) highlighted the difficulties Kenyan fish exporters face in meeting the stringent food safety requirements of the European Union. The study pointed out that the lack of comprehensive policies and effective regulatory mechanisms hampers the ability of fish processors to access lucrative international markets, thereby limiting the sector's growth potential.

There is also a barrier to value addition in terms of a lack of policy and legal framework for dried fish standards related to the export and domestic markets. There are no dried fish quality standards, for the domestic, regional, and international markets by the Kenya Bureau of Standards (KEBS) (Muma, 2015). The potential markets for dried fish products in these markets are huge. These markets are therefore lost because no value addition and trade in fish products is possible since the importation standards of overseas and regional countries cannot be met. For the domestic market, losses are incurred from costs for re-processing poor quality products and time loss (Muma, 2015).

Furthermore, the historical perception of fishing as a subsistence occupation has led to limited governmental support and resource allocation for the development of the fish value-addition sector. According to Ibuuri (2008), the Kenyan government initially overlooked the fishery resources, only recognizing their economic potential with the emergence of Nile perch for

export in the early 1990s. This delayed recognition has resulted in a policy environment that does not fully support the sector's needs, contributing to the slow growth and development of fish value-added products.

***Lack of knowledge and skills***

The lack of knowledge in the fish value-addition sector in Kenya encompasses several aspects, including awareness of value-added fish products, preparation and cooking skills, and the benefits associated with consuming these products. This lack of knowledge affects both producers and consumers, limiting the potential for growth and development in the sector (Kyule et al., 2014; Cheserek et al., 2022). In a study conducted by Cheserek et al. (2022) in Western Kenya, it was found that more than two-thirds of fish consumers did not consume value-added fish products such as samosas, fish fingers, fish balls, and fish fillets. However, the majority of consumers expressed a keen interest in incorporating value-added fish products into their diets, including feeding their babies with them. This low consumption rate was primarily due to the unavailability of these products and a lack of knowledge about their existence and preparation methods. The study highlighted that many consumers and fish traders were unaware of how to prepare and cook these products, which significantly hindered their adoption and incorporation into daily diets. This knowledge gap also limits the market for value-added fish products, reducing the economic opportunities for fish processors and traders (Cheserek et al., 2022).

Similarly, Kyule et al. (2014) reported that more than half of their respondents in Kirinyaga and Meru Counties consumed value-added fish products for the first time during market trials. This indicates a substantial lack of prior exposure and knowledge about these products among the population. The market trials provided an opportunity for consumers to experience these products, demonstrating the potential for increased demand if awareness and knowledge are improved (Kyule et al., 2014).

***Lack of market information***

Most fishermen and small-scale fish processors in Kenya have limited access to international markets due to a lack of comprehensive market information (Kimani et al., 2020). This information gap means they are often unaware of prevailing market prices and lucrative market opportunities abroad. According to Mwirigi and Theuri (2012), the marketing channels available to fishermen are insufficient and poorly linked, contributing to their ignorance of market dynamics. This disconnect in the value chain results in the sale of a significant portion of seafood products in their raw forms, with minimal value addition (Mwirigi & Theuri, 2012).

A study by Cheserek et al. (2022) in Western Kenya revealed that the lack of market information severely limits the ability of fish processors to expand their businesses and reach new markets. The study highlighted that many fish consumers and processors were not aware of the potential for value-added products such as fish samosas, fish fingers, and fish balls. This lack of awareness is largely due to insufficient market research and the absence of effective communication channels to disseminate market information. Moreover, the value chain for fish products in Kenya remains significantly underdeveloped, with little emphasis on value addition at various points along the chain. The weak linkages within the value chain indicate that opportunities for adding value through processing, packaging, and branding are often missed. As a result, most fish products are sold in their raw forms, which fetch lower prices than processed products. This situation underscores the need for better market information and stronger value chain linkages to enhance the competitiveness of Kenyan fish products.

The study by Kyule et al. (2014) also pointed out that the lack of market information contributes to the low consumption of value-added fish products in regions such as Kirinyaga and Meru Counties. The market trials conducted in these areas showed that when consumers were introduced to value-added products and provided with information about their benefits and availability, there was a significant increase in demand. This finding suggests that improving access to market information can play a crucial role in boosting the adoption of value-added fish products (Kyule et al., 2014). Addressing the lack of market information requires a coordinated effort to improve data collection, market research, and the

dissemination of market intelligence to all stakeholders in the fish value-addition sector. Government agencies, industry associations, and non-governmental organizations can play a pivotal role in bridging this information gap by establishing robust market information systems and conducting regular market research.

### *Areas for Improvement*

#### *Create awareness through training*

Improving consumer skills in preparing value-added fish products and improving the market performance of all fish species — through value addition, for example — will improve not only food security but also consumers' health and nutrition status. According to Githukia et al. (2014), women mostly participated in the peripheral parts of the fish value chain, such as post-harvest processing, marketing, and trading. Therefore, their participation in small-scale fisheries and the production of value-added fish products could lead to their empowerment, with greater control over income, resulting in purchasing and consuming nutritious foods and leading to the improvement of health care for children, and thus improved nutrition outcomes.

There is a need for comprehensive educational programs and extension services that can enhance the knowledge and skills of both producers and consumers. A study by Acharjee et al. (2023) in Bangladesh found that factors such as farmer education, fish farming experience, and access to extension services positively influenced decisions around value addition, while older age had a negative effect. These findings underscore the importance of tailored extension services in developing a modern and efficient fish market system. Training programs should focus on the benefits of consuming value-added fish products, preparation and cooking techniques, and ways to incorporate these products into daily diets. Additionally, creating awareness about the availability and advantages of value-added fish products through marketing campaigns can help increase their adoption and consumption.

Despite the challenges facing the fish value-addition sector in Kenya, numerous opportunities for growth and development can be harnessed to enhance the sector's productivity, competitiveness, and sustainability. These opportunities include improving regulatory and quality control standards, increasing access to capital and technology, investing in infrastructure, enhancing research and development, strengthening policy and legal frameworks, increasing knowledge and skills, and improving market information systems.

#### *Improving regulatory and quality control standards*

Improving regulatory and quality control standards presents a significant opportunity for growth and development in Kenya's fish value-addition sector. Strengthening these standards can enhance product quality, boost consumer confidence, and open up new markets, particularly for exports (Ababouch, 2006). One key opportunity lies in enforcing the existing standards and aligning Kenya's fish processing standards with internationally accepted standards, such as the Codex Alimentarius, which are already used for imported fish. These standards can be applied to value-added fish products consumed locally, ensuring high food safety and quality. The safety standards applied by Kenya, which are the European Union (EU) standards that have been adopted in domestic settings, emphasize the importance of meeting stringent food safety requirements (Henson et al., 2000). Ensuring compliance with these standards through improved regulatory frameworks can significantly enhance the export potential of Kenyan fish products and increase their competitiveness on the global stage.

The improvement of regulatory and quality control standards has shown promise especially on the global stage. The benefits of implementing HACCP systems are well documented in other countries. For example, a study by Qatan et al. (2015) in the Sultanate of Oman reported that the top five advantages identified by stakeholders included: improved product quality and easier market access; entry into markets with stringent quality requirements; enhanced customer satisfaction; better quality control; and improved employee morale and commitment to quality. Notably, the adoption of HACCP significantly reduced product rejections in the European Union (EU) market, with only one case reported in 2009. Okpala and Korzeniowska (2023) reported that

the adoption of ISO 9001:2015, a leading global standard for quality management, assures consistency in product quality improvement regardless of the field of activity and size of the company. ISO 22000, a management system standard favored by the agro-food industry, unifies standards across different food chains internationally through the issuance of certificates. By 2014, more than 30,000 ISO 22000 certificates had been issued worldwide, illustrating the standard's widespread adoption and impact. These regulatory controls have significantly improved food product quality and consumer protection/safety through the practice of quality assurance, good hygiene practices, legislative and regulatory standards, and other quality-related processes.

### *Affordable financing options and modern technology*

Access to affordable financing enables fish farmers and processors to invest in modern technologies that enhance productivity and product quality (Allison, 2011). This financial support is critical in bridging the gap between traditional practices and modern, efficient methods that can boost the sector's overall performance. To expand financing options, tailored microfinance models, such as group lending schemes and rotating savings and credit associations (ROSCAs), can be introduced for artisanal processors and small-scale traders. Furthermore, access to finance and research and development (R&D) have a strong relationship with export performance and value addition. Operatives with greater access to finance and R&D capabilities tend to exhibit stronger export performance, as they can invest in advanced processing technologies, quality control measures, and market expansion strategies (Jaabi, 2014). These investments enable fish operatives to produce higher-value products that meet international standards, thus enhancing their competitiveness in global markets. This correlation supports the general theory that financial access and technological advancements are critical for improving export performance and value addition (Jaabi, 2014).

Rowan, (2023) also notes that modern digital technologies can inform novel fish and seafood processing, including the potential for future automation, training, and improved standardization. Thus, digitalization will support and enable our ability to make informed decisions on the use and protection of our natural resources. There is a pressing need to conduct a life-cycle assessment that is aligned with developing e-waste recycling technologies that will be met through better infrastructure, upskilled staff, and appropriate policies (Rowan, 2023). To accelerate technology adoption, public-private partnerships (PPPs) should be leveraged to co-finance digital traceability tools, cold chain logistics, and automated processing systems. Mahmud et al. (2020), in a study on factors influencing value addition on the Kenyan coast, also recommended that fish traders should increase their internal capabilities by adopting modern technologies and equipment to enhance fish value addition activities. Additionally, targeted government subsidies or tax incentives can be introduced to lower the cost of essential processing equipment, making modern technology more accessible to small and medium enterprises (SMEs).

### *Investment in infrastructure*

One of the significant challenges faced by the fish value-addition sector in Kenya is the lack of adequate cold storage facilities. This inadequacy leads to significant post-harvest losses, impacting the sector's profitability and sustainability. By investing in modern cold storage and refrigeration facilities, fish products can be preserved for extended periods, reducing spoilage and maintaining quality from harvest to the market (Maulu et al., 2020). Cold storage hubs should be established in high-production areas and equipped with solar-powered refrigeration systems, supported through public-private partnerships (PPPs) to reduce electricity costs and ensure sustainability. This investment is crucial for ensuring fish products meet local and international quality standards, thus enhancing their marketability. Transportation infrastructure also plays a vital role in the fish value-addition chain. Efficient and reliable transportation networks are essential for timely fish movement from production sites to processing facilities and markets. Improved roads, ports, and logistics systems can reduce transportation costs and times, lowering the overall cost of fish products and

making them more competitive. Moreover, better transportation infrastructure facilitates access to remote fishing areas, expanding the supply base and supporting the growth of the fish value-addition sector (Kimani et al., 2020). Upgrading feeder roads that link major landing sites with processing zones using county-level infrastructure funds would reduce transit time and spoilage, especially during peak seasons.

Processing plants are another critical component of infrastructure investment. Modern processing facilities equipped with advanced technology can enhance the value of fish products through activities such as filleting, packaging, and canning. These value-added processes improve the quality and shelf life of fish products and increase their market value. Deploying mobile modular fish processing units that are co-financed through development grants and SME credit programs can expand reach to underserved rural areas and support artisanal processors. Investments in processing infrastructure can also create job opportunities and stimulate economic development in local communities (Montgomery et al., 2022). For example, India's well-equipped fish processing units that are built to meet the quality and regulatory standards of major markets such as the EU and the USA have contributed significantly to the country's expanding seafood exports. Kenya can draw valuable lessons from such models to build a more resilient, inclusive, and competitive fish value-addition sector (Ravishankar & Elavarasan, 2024)

Moreover, developing aquaculture infrastructure, including hatcheries and feed mills, is essential for supporting the sustainable growth of the fish value-addition sector. Well-equipped hatcheries can provide high-quality fingerlings, while efficient feed mills can produce affordable and nutritious fish feed. These facilities are fundamental for increasing fish production and ensuring the availability of raw materials for value addition (Munguti et al., 2021). Establishing regional aquaculture innovation centers that integrate hatchery services, feed production, and technical extension would help build local capacity and ensure year-round production continuity.

***Enhancing Research and Development (R&D)***

Increasing investment in R&D can lead to significant innovations in fish processing, packaging, and marketing, ultimately boosting the sector's competitiveness both locally and internationally. Investing in R&D allows for the exploration and adoption of new technologies and methods that can improve the efficiency and quality of fish processing (Kulradathon, 2021). For instance, advanced processing techniques can increase the shelf-life of fish products, reduce post-harvest losses, and enhance product safety and quality (Mboya et al., 2023). By integrating modern packaging technologies, producers can ensure that fish products maintain their freshness and appeal during transportation and storage, thereby meeting the high standards required by export markets.

Research institutions and universities play a crucial role in this development by collaborating with industry stakeholders to conduct in-depth studies on consumer preferences, market trends, and best practices in fish value addition. Such collaborations can help identify and develop new value-added products tailored to specific market demands. For example, studies by Esilaba et al. (2017) have shown that understanding urban consumer preferences in Nakuru Town can guide the development of fish products that meet the unique tastes and expectations of different consumer segments. This consumer-centric approach can significantly enhance the marketability and acceptance of fish products, driving growth in the sector.

Moreover, R&D can help improve existing fish value-added products by optimizing production processes and introducing innovative solutions. For instance, research on better preservation methods or more efficient processing technologies can reduce costs and improve the profitability of fish value-added products. By continuously refining these processes, the industry can maintain a competitive edge in the market (Esilaba et al., 2017). The benefits of enhancing R&D are not limited to technological advancements alone. R&D can also provide valuable insights into sustainable practices that ensure the long-term viability of fish resources. Researchers can develop strategies that minimize ecological

damage and promote sustainable fishery practices by studying the environmental impacts of different fishing and processing methods. This is crucial for ensuring that the fish value-addition sector can continue to thrive without depleting natural resources (Wang & Azam, 2024).

***Strengthening policy and legal framework***

Developing and implementing comprehensive policies and legal frameworks that support the fish value-addition sector is essential for providing a stable and conducive environment for all stakeholders. Clear and consistent regulations on food safety, quality standards, and export requirements can significantly enhance the sector's stability and attractiveness to investors (Theuri, 2015). A robust policy framework ensures that fish products meet international standards, thereby enhancing their competitiveness in global markets. For instance, the study by Njiru et al. (2021) highlights the potential of Kenya's marine fisheries for economic growth through value addition, which could be substantially realized with strong policy support (Kimani et al., 2020). Such policies would not only improve the quality of fish products but also ensure that they are safe for consumption, thereby boosting consumer confidence both locally and internationally.

Moreover, policies that promote sustainable fishing practices are crucial for the long-term viability of the fish value-addition sector (Stevens et al., 2018). Sustainable fishing practices ensure that fish populations are not depleted, thus guaranteeing a continuous supply of raw materials for value addition. This can be achieved through regulations that control fishing quotas, protect breeding grounds, and promote aquaculture as an alternative to overfishing in natural waters (Aloo et al., 2017).

Another critical component of an effective policy framework is providing incentives for value addition. These incentives can take various forms, such as tax breaks, subsidies, and grants for businesses involved in fish processing and marketing (Mwaijande & Lugendo, 2015). By reducing the financial burden on these businesses, the government can stimulate investment and innovation in the sector, leading to the development of new and improved fish products.

***Improving Market Information Systems***

Improving market information systems is a crucial opportunity for growth and development in Kenya's fish value-addition sector. Developing robust market information systems can bridge the gap in market knowledge and help stakeholders make informed decisions (Quagrainie et al., 2007). Government agencies, industry associations, and non-governmental organizations can collaborate to collect, analyze, and disseminate market data on prices, trends, and opportunities. This information can help fish processors identify lucrative markets, set competitive prices, and tailor their products to meet consumer needs, thereby enhancing their market reach and profitability.

A well-functioning market information system ensures that all stakeholders in the fish value-addition sector have access to timely and accurate information (Haimbala, 2019). For example, the study by Njiru et al. (2021) highlighted the importance of reliable market data in exploiting Kenya's marine fisheries for economic growth. With comprehensive data on market trends and consumer preferences, fish processors can develop strategies to meet the demands of both local and international markets, thus driving economic development in the sector.

Moreover, robust market information systems can help mitigate risks associated with market volatility. These systems enable fish processors and traders to make informed decisions that can reduce losses and enhance profitability by providing real-time updates on fish prices and market conditions. Aloo et al. (2017) discussed how improved market information can support aquaculture development in Kenya, contributing to poverty alleviation and food security by ensuring that fish products are competitively priced and widely available.

## Conclusions

This review provides the first comprehensive synthesis of Kenya's fish value-added products, consolidating fragmented data on product types, processing technologies, market dynamics, and policy barriers. It offers a timely resource for policymakers, industry stakeholders, and development practitioners seeking to enhance the sector's efficiency, profitability, and contribution

to national development. By illuminating both the existing bottlenecks such as weak regulatory enforcement, limited infrastructure, and inadequate access to technology and capital and the sector's underexploited opportunities, this study lays a clear foundation for evidence-based interventions. This integrated approach bridges technical, economic, and policy perspectives, offering a fresh lens to guide decision-making and stimulate investment in value-added fish enterprises. With strategic support, Kenya's fish value-added sector holds immense potential to unlock regional export markets, enhance food and nutrition security, create jobs, and uplift rural livelihoods. In the long term, strengthening this subsector will not only contribute to blue economy growth but also advance Kenya's broader sustainability and economic resilience goals.

**Ethical approval**

The authors declare that this review complies with research and publication ethics.

**Informed consent**

Not available.

**Conflicts of interest**

There is no conflict of interest in publishing this review.

**Data availability statement**

Data sharing does not apply to this article as no new data is created or analyzed in this study

**Funding organizations**

No funding available.

**Author contribution**

Authors are encouraged to submit an "Author statement" providing individual contributions of authors such as:

Domitila: Writing original draft, Conceptualization, Formal analysis

Jonathan: Writing original draft, Investigation, Methodology

Mavindu: Writing original draft, Conceptualization, Supervision

Mary: Writing original draft, Resources, Review, Editing.

Jacob Abwao: Writing original draft, Validation, Review

Anne Maundu: Writing original draft, Validation, Editing.

**References**

Ababouch, L. (2006). Assuring fish safety and quality in international fish trade. Marine pollution bulletin, 53(10-12), 561-568. https://doi.org/10.1016/j.marpolbul.2006.08.011

Abiodun-Solanke, A. O. (2020). 6 Fish and shellfish processing. *Food Science and Technology: Trends and Future Prospects*, 153. https://doi.org/10.1515/9783110667462-006

Acharjee, D. C., Alam, G. M., Gosh, K., Haque, A. M., & Hossain, M. I. (2023). Fish value chain and the determinants of value addition decision: Empirical evidence from Bangladesh. *Journal of the World Aquaculture Society*, *54*(4), 931-944. https://doi.org/10.1111/jwas.12941

Akullo, D. O. (2023). *Food Safety and Free Trade Area in East Africa* (Doctoral dissertation, Walden University). https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=13164&context=dissertations (Accessed 22nd August 2024)

Alliance, G. C. C. (2016). Kenya cold chain assessment. https://www.gcca.org/legacy-system/Kenya%20Cold%20Chain%20Assessment%20final%20report%202%2016%2018.pdf (Accessed 24th August 2024)

Allison, E. (2011). Aquaculture, fisheries, poverty and food security. WordFish Working Paper 2011-65. The WorldFish Center, Penang, Malaysia. https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/1163/WF_2971.pdf?sequence=1&isAllowed=y (Accessed 29th July 2024)

Aloo, J. O. (2014). *Development of refined oil from Lake Victoria Nile perch (Lates niloticus) viscera* (Doctoral dissertation). http://erepository.uonbi.ac.ke/bitstream/handle/11295/74237/Thesis%20Corrected%20-%20Final-Editted.pdf?sequence=3 (Accessed 15th August 2024).

Aloo, P. A., Charo-Karisa, H., Munguti, J., & Nyonje, B. (2017). A review on the potential of

aquaculture development in Kenya for poverty alleviation and food security. *African Journal of Food, Agriculture, Nutrition and Development*, *17*(1), 11832-11847. https://doi.org/10.18697/ajfand.77.15585

Ayuya, O. I., Soma, K., & Obwanga, B. (2021). Socio-economic drivers of fish species consumption preferences in Kenya's urban informal food system. *Sustainability*, *13*(9), 5278. https://doi.org/10.3390/su13095278

Banna, M. H. A., Al Zaber, A., Rahman, N., Siddique, M. A. M., Siddique, M. A. B., Hagan Jr, J. E., & Khan, M. S. I. (2022). Nutritional value of dry fish in Bangladesh and its potential contribution to addressing malnutrition: a narrative review. *Fishes*, *7*(5), 240. https://doi.org/10.3390/fishes7050240

Barros, D., Nova, P., Cunha, S., Monteiro, V., Fernandes, É., Pereira-Pinto, R., & Vaz-Velho, M. (2023). Enhancing storage stability of smoke-flavored horse mackerel filets using natural extracts as preservatives. *Frontiers in Sustainable Food Systems*, *7*, 1296265. https://doi.org/10.3389/fsufs.2023.1296265

Binsi, P. K. and Parvathy, U. (2021) Development of value added fish products. In: Ravishankar, C.N., K. Ashok Kumar, Leela Edwin, Susheela Mathew, A. K Mohanty, Zynudheen A. A, George Ninan, Toms C Joseph, V.Chandrasekar, Sajesh V.K, Prajith K. K, Renuka, Laly S. J., Sreelakshmi. K. R, Ranjit K. Nadella & Murali S. (eds.) (2021). Recent advances in harvest and post-harvest technologies in fisheries (Training Manual), ICAR-Central Institute of Fisheries Technology, Cochin, India. pp.168-176. http://krishi.icar.gov.in/jspui/handle/123456789/70415

Binsi, P. K., & Parvathy, U. (2019). Value addition of cultivatable and capture fishery resources: Present and future dimensions. ICAR-Central Institute of Fisheries Technology. https://drs.cift.res.in/bitstream/handle/123456789/4516/Value%20addition%20of%20cultivable%20and%20capture%20fishery%20resources.pdf?sequence=1 (Accessed 16th July 2024)

Cheruiyot, S. J., Kimanthi, M., Shabani, J. S., Nyamu, N. F., Gathu, C., Agoi, F., & De Meijer, F. (2022). Climate change poses a threat to nutrition and food security in Kilifi County, Kenya. *African Journal of Primary Health Care & Family Medicine*, *14*(1). https://doi.org/10.4102/phcfm.v14i1.3718

Cheserek, M. J., Obiero, K. O., Menach, E., & Ogello, E. O. (2022). Fish and fish products consumption behaviours and attitudes of farmers in Western Kenya. *African Journal of Food, Agriculture, Nutrition and Development*, *22*(9), 21503-21527. https://doi.org/10.18697/ajfand.114.21550

Danilyuk, M., Ishevsky, A., & Naumova, A. (2024). Minced fish enriched with OMEGA-3 and OMEGA-6 for gerontological nutrition. In *E3S Web of Conferences* (Vol. 539, p. 02023). EDP Sciences. https://doi.org/10.1051/e3sconf/202453902023

Duru, H., Odhiambo, L., & Wang, T. (2009). Chinese and Kenyan food culture-information for health care personnel in Finland. https://www.theseus.fi/bitstream/handle/10024/5978/Duru_Hilary_Odhiambo_Larvine_Wang_Tianci.pdf?sequence=1 (Accessed 25th July 2024)

Ekholuenetale, M., Barrow, A., Ekholuenetale, C. E., & Tudeme, G. (2020). Impact of stunting on early childhood cognitive development in Benin: evidence from Demographic and Health Survey. *Egyptian Pediatric Association Gazette*, *68*, 1-11. https://doi.org/10.1186/s43054-020-00043-x

Eshari, F., Keley, M. T., Habibi-Rezaei, M., & Tajeddini, S. (2022). A review of the fish oil extraction methods and omega 3 concentration technologies. *Food Processing and Preservation Journal*, 14 (3), 101-124. https://doi.org/10.22069/FPPJ.2022.20004.1700

Esilaba, F. A., Moturi, W. N., & Mokua, M. A. (2017). Urban consumers' fish preferences and the determinants influencing fish selection and consumption: Case study of Nakuru Town, Kenya. *International Journal of Fisheries and Aquatic Studies*, *5*(3), 356-360. https://www.academia.edu/download/76337093/5-2-70-941.pdf

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

Githukia, C. M., Obiero, K. O., Manyala, J. O., Ngugi, C. C., Quagrainie, K. K. (2014). Consumer Perceptions, and Preferences of Wild and Farmed Nile Tilapia (*Oreochromis niloticus L.*) and African Catfish (*Clarias gariepinus* Burchell 1822) in Urban Centres in Kenya. *International Journal of Advanced Research*, 2(7) 694-705. https://www.academia.edu/download/42123743/Consumer_Perceptions_and_Preferences_of_20160205-26868-lib0w4.pdf

Haimbala, T. (2019). Sustainable growth through value chain development in the blue economy: a case study of the port of Walvis Bay. https://commons.wmu.se/cgi/viewcontent.cgi?article=2122&context=all_dissertations (Accessed 19th August 2024)

Hasan, M. R., Bueno, P. B., & Corner, R. A. (2020). Strengthening, empowering and sustaining small-scale aquaculture farmers' associations. *FAO Fisheries and Aquaculture Technical Paper*, No. 655. Rome, FAO. 190 pp.. https://doi.org/10.4060/c7741en

Henson, S., Brouder, A. M., & Mitullah, W. (2000). Food safety requirements and food exports from developing countries: the case of fish exports from Kenya to the European Union. *American Journal of Agricultural Economics*, *82*(5), 1159-1169. https://doi.org/10.1111/0002-9092.00115

Herdiana, N., & Widaputri, S. (2022). Sensory and Chemical Properties of Long Jawed Mackerel (Rastrelliger kanagurta L.) Fish Balls with Addition of Canna (Canna edulis Kerr.) Starch Concentration as a Filler. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1036, No. 1, p. 012022). IOP Publishing. https://doi.org/10.1088/1755-1315/1036/1/012022

Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., & Pluye, P. (2018). The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for information*, *34*(4), 285-291. https://doi.org/10.3233/EFI-180221

Ibuuri, P. K. (2008). Current Status of Fishery Resources in Kenya. *Journal of Marine Bioscience and Biotechnology*, *3*(1), 24-30. https://doi.org/10.3390/foods13040565

Iman, A., Rios-Mera, J. D., Rengifo, E., Palomino, F., Vela-Paredes, R., Vásquez, J., ... & Tello, F. (2024). A Comparative Study of Freshwater Fish Burgers Made from Three Amazonian Species: Omega 3 Fortification and Sodium Reduction. *Foods*, *13*(4), 565. https://doi.org/10.3390/foods13040565

Issifu, I., Deffor, E. W., Deyshappriya, N. P. R., Dahmouni, I., & Sumaila, U. R. (2022). Drivers of seafood consumption at different geographical scales. *Journal of Sustainability Research*, *4*(3). https://wap.hapres.com/htmls/JSR_1496_Detail.html

Jaabi, S. A. (2014). *Enterprise finance and economic development: a study of the fishing industry in Uganda and the Gambia*. University of Malaya, Malaysia. http://studentsrepo.um.edu.my/4715/1/Seeku-Thesis_Final_Copy.pdf

Khalili Tilami, S., & Sampels, S. (2018). Nutritional value of fish: lipids, proteins, vitamins, and minerals. *Reviews in Fisheries Science & Aquaculture*, *26*(2), 243-253. https://doi.org/10.1080/23308249.2017.1399104

Kimani, P., Adrien, B., Ward, A., & Ahern, M. (2022). *Post-harvest practices for empowering women in small-scale fisheries in Africa: Successful outcomes and guidance.* FAO Fisheries and Aquaculture Circular No. 1241. Rome, FAO. https://doi.org/10.4060/cb7918en

Kimani, P., Wamukota, A., Manyala, J. O., & Mlewa, C. M. (2020). Analysis of constraints and opportunities in marine small-scale fisheries value chain: A multi-criteria decision approach. *Ocean & Coastal Management*, *189*, 105151. https://doi.org/10.1016/j.ocecoaman.2020.105151

KNBS (2024). Economic Survey 2024. National Bureau of Statistics, Nairobi, Kenya, 480 pp.

Kulradathon, S. (2021). The role of research and development as a strategy for SMEs development with particular reference to the case of the fisheries and seafood sector in Thailand. http://stax.strath.ac.uk/downloads/5x21tf804 (Accessed 15th August 2024)

Kyule, D. N., Fonda, J. A., Ochiewo, J., Munguti, J. M., Obiero, K. O., Ogello, E. O., ... & Kendi, J. (2020). Perceived consumer preferences of fisheries products retailed in Kenyan markets. *Bioscience Research*, 17(4): 2486-2496. http://edocs.maseno.ac.ke/bitstream/handle/123456789/4653/Bioscience%20paper%20preference%20%281%29.pdf?sequence=1&isAllowed=y

Kyule, D. N., Yongo, E., Opiyo, M. A., Obiero, K., Munguti, J. M., & Charo-Karisa, H. (2014). Fish product development and market trials of fish and fish products in Kenya: a case study of Kirinyaga and Meru Counties. *Livestock Research for Rural Development*, *26*(6), 1-9. https://www.academia.edu/download/53242135/Fish_product_development_and_market_tria20170523-28128-1hwdsgw.pdf

Kyule, D., Opiyo, M. A., Ogello, E., Obiero, K., Maranga, B., Orina, P., ... & Munguti, J. (2016). Determination of fish value added product-preferences among the residents of wote town, Makueni county, Kenya. *Bulletin of Animal Health and Production in Africa*, 69. http://repository.au-ibar.org/xmlui/bitstream/handle/123456789/537/Special%20Edition_Fisheries%20and%20Aquaculture%20Resources.pdf?sequence=1&isAllowed=y#page=69

Kyule-Muendo, D., Awuor, F. J., Githukia, C., Kendi, J., Mziri, V., Obiero, K., & Orina, P. (2021). Post-Harvest Management, Value Addition and Fish Marketing. In: Munguti et al., (Eds). State of Aquaculture in Kenya 2021: Towards Nutrition-Sensitive Fish Food Production Systems; Chapter 6: pp 103–112. https://kmfri.go.ke/ALL/images/pdf/reports/State_of_Aquaculture_in_KE_2021_Report_final_report_Published.pdf

Lithi, U. J., Faridullah, M., Uddin, M. N., Mehbub, M. F., & Zafar, M. A. (2020). Quality evaluation of mince-based fish burger from tilapia (Oreochromis mossambicus) during frozen storage. https://doi.org/10.5455/JBAU.86202

Lokuruka, M.N. (2021). Food and Nutrition Security in East Africa (Kenya, Uganda and Tanzania): Status, Challenges and Prospects. IntechOpen, 1-28. https://doi.org/10.5772/intechopen.95036

Magesa, R. J., Sewando, P., & Mkenda, L. D. (2024). Fish Value Addition Practices by Women Fish Vendors in Dar Es Salaam: A Case of Mackerel Fish. *East African Journal of Business and Economics*, *7*(1), 63-71. https://doi.org/10.37284/eajbe.7.1.1793

Mahmud, S. S., Mathuva, E., & Mwenda, P. K. (2020). *Factors Influencing Value Addition among Fish Traders in Mombasa County, Kenya*. Masters Thesis, Keya Methodist University. http://repository.kemu.ac.ke/bitstream/handle/123456789/1310/Swaleh.pdf?sequence=1&isAllowed=y (Accessed 23rd August 2024)

Maina, B. J. (2011). *Analysis Of Market Performance: A Case Of Omena Fish In Selected Outlets In Kenya*. A Masters Thesis, Egerton University. https://aquadocs.org/bitstream/handle/1834/7323/ktf0288.pdf?sequence=1&isAllowed=y (Accessed 5th August 2024)

Manyala, J.O. & Adoyo, R. (2011). A study on marketing of high quality Omena in the major urban centres in Kenya. Promotion of Private Sector Development, Republic of Kenya.

Maulu, S., Hasimuna, O. J., Monde, C., & Mweemba, M. (2020). An assessment of post-harvest fish losses and preservation practices in Siavonga district, Southern Zambia. *Fisheries and aquatic sciences*, *23*(1), 25. https://doi.org/10.1186/s41240-020-00170-x

Mboya, J. B., Obiero, K. O., Cheserek, M. J., Ouko, K. O., Ogello, E. O., Outa, N. O., ... & Munguti, J. M. (2023). Factors influencing farmed fish traders' intention to use improved fish post-harvest technologies in Kenya: application of technology acceptance model. *Fisheries and Aquatic Sciences*, *26*(2), 105-116. https://doi.org/10.47853/FAS.2023.e9

Mehta, N. K., Sharma, S., Triphati, H. H., Satvik, K., Aruna, K., Choudhary, B. K., & Meena, D. K. (2023). Conversion of fish processing waste to value-added commodities: a waste to wealth strategies for greening of the environment. In *Advances in Resting-state Functional MRI* (pp. 421-466). Woodhead Publishing. https://doi.org/10.1016/B978-0-323-99145-2.00005-7

Montgomery, S., Subasinghe, R. P., Siriwardena, S. N., & Shelley, C. C. (2022). Nigerian aquaculture: An investment Framework for Improved Incomes, New Jobs, Enhanced Nutritional Outcomes and Positive Economic Returns. Penang, Malaysia: WorldFish. Program Report: 2022-10. https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/5331/6cb994de392d6f7b24d2252f6f34ec7b.pdf?sequence=2&isAllowed=y (Accessed 13th August 2024)

Muma, M. (2015). *Barriers to Value Addition in" Omena" Fisheries Value Chain in Kenya*. Kenya Institute for Public Policy Research and Analysis. https://repository.kippra.or.ke/xmlui/bitstream/handle/123456789/2246/barriers-to-value-addition-in-omena-fisheries-value-chain-in-kenya-dp178.pdf?sequence=1&isAllowed=y (Accessed 15th August 2024).

Munguti, J. M., Kirimi, J. G., Obiero, K. O., Ogello, E. O., Sabwa, J. A., Kyule, D. N., ... & Musalia, L. M. (2021). Critical aspects of aquafeed value chain in the Kenyan aquaculture sector-a review. *Sustainable Agriculture Research*, 10(2); 87-97. https://doi.org/10.5539/sar.v10n2p87

Mwaijande, F. A., & Lugendo, P. (2015). Fish-farming value chain analysis: Policy implications for transformations and robust growth in Tanzania. *Journal of Rural and Community Development*, *10*(2). https://journals.brandonu.ca/jrcd/article/download/1120/265

Mwanja, M. T., & Munguti, J. (2010). Characterisation of fish oils of mukene (Rastrineobola argentea) of Nile basin waters-Lake Victoria, Lake Kyoga and the Victoria. *Tropical Freshwater Biology*, *19*(1), 49-58. https://www.academia.edu/download/51105499/CHARACTERISATION_OF_FISH_OILS_OF_MUKENE_20161229-11489-rtj133.pdf

Mwirigi, F. M., & Theuri, F. S. (2012). The challenge of value addition in the seafood value chain along the Kenyan north coast. International Journal of Business and Public Management, 2(2), 51-56. http://hdl.handle.net/1834/8873.

Ngaruiya, F. W. (2021). *Fisherfolk Exposure to Human Health Risks Through Fish Handling and Processing at Kampi Samaki, Lake Baringo, Kenya* (Doctoral dissertation, Egerton University). http://41.89.96.81:4000/bitstreams/1c823c80-2ce5-46e3-a480-204e642f9dbe/download

Ninan, G. (2018). Fish Processing and Value Addition–A Global Scenario. ICAR-Central Institute of Fisheries Technology. https://drs.cift.res.in/bitstream/handle/123456789/4479/Fish%20processing%20and%20value%20addition.pdf?sequence=1 (Accessed 19th August 2024)

Ninan, G. (2021). Handling, Chilling and Freezing of Fishery Products. ICAR-Central Institute of Fisheries Technology. https://krishi.icar.gov.in/jspui/bitstream/123456789/70443/1/5.pdf (Accessed 15th August 2024)

Ninan, G. (2022). Quality and safety issues in coated fish products: industry perspective. In: Leela Edwin., Zynudheen, A. A., Mohanty, A. K., Femeena Hassan, Panda, S. K., Laly, S. J., Pankaj Kishore, Ranjit Kumar Nadella, Devananda Uchoi, Priya, E. R. and Chandrasekar, V. (eds.) (2022) Quality assurance of fish and fishery products, Central Institute of Fisheries Technology, Cochin, India. pp 143-169. http://krishi.icar.gov.in/jspui/handle/123456789/78371

Njiru, J., Omukoto, J. O., Kimani, E. N., Aura, C. M., & Van der Knaap, M. (2021). Kenya marine fisheries: The next frontier for economic growth?. *Aquatic Ecosystem Health & Management*, *24*(1), 97-104. https://doi.org/10.14321/aehm.024.01.14

Njiru, M., Kazungu, J., Ngugi, C. C., Gichuki, J., & Muhoozi, L. (2008). An overview of the current status of Lake Victoria fishery: Opportunities, challenges, and management strategies. *Lakes & Reservoirs: Research & Management*, *13*(1), 1-12. https://doi.org/10.1111/j.1440-1770.2007.00358.x

Nkrumah, T. (2015). *Using mackerel (Scomberomorus tritor) and catfish (Clarias gariepinus) in frankfurter-type sausages*. Doctoral dissertation, Kwame Nkrumah University of Science and Technology.

https://ir.knust.edu.gh/bitstreams/42f8adee-43d2-4056-a647-d0514d41dd18/download (Accessed 18th August 2024)

Nyamwaka, I. S., Monda, E., Ombori, O., & Kwach, J. (2020). Sources of Fungal Contamination of Fresh and Dried Fish in Kisii County, Kenya. *Microbiology Research Journal International*, *30*(10), 50-62. https://doi.org/10.9734/mrji/2020/v30i1030273

Nyawade, O. B., Were-Kogogo, P., Owiti, P., Osimbo, H., & Daniel, A. O. (2021). Elusive fish catch and vulnerable livelihoods: Status of fishing and fisheries industry among marine south coast communities of Kwale, Kenya. *Archives of Agriculture and Environmental Science*, *6*(2), 149-159. https://doi.org/10.26832/24566632.2021.060206

Obiero, K. O., Opiyo, M. A., Munguti, J. M., Orina, P. S., Kyule, D., Yongo, E., ... & Charo-Karisa, H. (2014). Consumer preference and marketing of farmed Nile Tilapia (*Oreochromis niloticus*) and African Catfish (*Clarias gariepinus*) in Kenya: case study of Kirinyaga and Vihiga Counties. *International Journal of Fisheries and Aquatic Studies*, *1*(5), 67-76. https://www.academia.edu/download/53242138/Consumer_preference_and_marketing_of_far20170523-28131-1ytaus8.pdf

Obiero, K., Munguti, J., Ani, J., and Liti, D. (2019). Inventory of climate-smart agriculture technologies, innovations and management practices (TIMPS) for aquaculture value chain. https://www.kcsap.go.ke/sites/default/files/manual/AQUACULTURE.pdf

Ochieng, O. B., Oduor, O. P. M., & Nyale, M. M. (2015). Biochemical and nutritional quality of dried sardines using raised open solar rack dryers off Kenyan coast. *Journal of Food Resource Science*, *4*(2), 33-42. https://doi.org/10.3923/jfrs.2015.33.42

Odoli, C. O., Owiti, H., Kobingi, N., Obiero, M., Ogari, Z., Mugo, J., ... & Aura, C. M. (2019). Post-harvest interventions in small-scale fisheries: a boon or bane to food and nutritional security in Kenya?. *Food security*, *11*, 855-868. https://doi.org/10.1007/s12571-019-00950-x

Odour-Odote, P. M. (2020). *Effect of natural antioxidants on protein and lipid oxidation in fish (Siganus sutor) processed in a locally fabricated hybrid windmill-solar tunnel dryer*. Doctoral dissertation, University of Surrey. https://openresearch.surrey.ac.uk/esploro/fulltext/doctoral/Effect-of-natural-antioxidants-on-protein/99514912002346?repId=12139551750002346&mId=13140275720002346&institution=44SUR_INST

Ogello, E., Tran, N., Outa, N., Muthoka, M., & Hoong, Y. (2023). Promising Aquaculture Technologies and Innovations for Transforming Food Systems Toward Low Emission Pathways in Kenya: A Review. Penang, Malaysia: WorldFish. Working Paper. https://cgspace.cgiar.org/bitstream/handle/10568/136166/d602e1c444820f23d4d643e399115e97.pdf?sequence=-1 (Accessed 18th August 2024)

Okpala, C. O. R., & Korzeniowska, M. (2023). Understanding the relevance of quality management in agro-food product industry: From ethical considerations to assuring food hygiene quality safety standards and its associated processes. *Food Reviews International*, *39*(4), 1879-1952. https://doi.org/10.1080/87559129.2021.1938600

Omega, M. (2023). A preliminary assessment of the post-harvest fish losses along selected fish supply chains in Kwale County, Kenya. *A Scientific Journal of Kenya Marine and Fisheries Research Institute*, 6. https://www.vliz.be/imisdocs/publications/390711.pdf#page=6

Opiyo, R. O., Nyasulu, P. S., Koigi, R. K., Obondo, A., Ogoyi, D., & Kogi-Makau, W. (2018). Effect of fish oil omega-3 fatty acids on reduction of depressive symptoms among HIV-seropositive pregnant women: a randomized, double-blind controlled trial. *Annals of General Psychiatry*, *17*, 1-16. https://doi.org/10.1186/s12991-018-0220-4

Owaga, E. E., Onyango, C. A. and Njoroge, C. K. (2009). Investigation of mycoflora on dagaa (*Rastreneobola argentea*) as affected by washing and drying methods. *Journal of Applied Bioscience*, 19, 1074-1081. https://repository.dkut.ac.ke:8080/xmlui/bitstream/handle/123456789/7682/Investigation%20of%20mycoflora%20on%20dagaa%20%28Rastreneobola.pdf?sequence=1&isAllowed=y

Paci, F., Danza, A., Del Nobile, M. A., & Conte, A. (2018). Consumer acceptance and willingness to pay for a fresh fish-burger: A choice experiment. *Journal of cleaner production*, *172*, 3128-3137. https://doi.org/10.1016/j.jclepro.2017.11.095

Page, M. J., & Moher, D. (2017). Evaluations of the uptake and impact of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement and extensions: a scoping review. *Systematic reviews*, *6*, 1-14. https://doi.org/10.1186/s13643-017-0663-8

Patrick, M. (2021). *Growth performance of tilapia in different culture systems on varying input amounts and aquaculture technologies adoption in Meru county, Kenya*. Doctoral dissertation, Kenyatta University. https://ir-library.ku.ac.ke/server/api/core/bitstreams/7aedd109-39ee-4221-b557-9979080d9dd1/content

Peñarubia, O., Toppe, J., Ahern, M., Ward, A., & Griffin, M. (2023). How value addition by utilization of tilapia processing by-products can improve human nutrition and livelihood. *Reviews in Aquaculture*, *15*, 32-40. https://doi.org/10.1111/raq.12737

Qatan, S., Bose, S., & Mothershaw, A. (2015). Stakeholders' views on the status of the fish quality and safety regulatory schemes: The case of the sultanate of Oman. *British Food Journal*, *117*(4), 1303-1314. https://doi.org/10.1108/BFJ-12-2013-0359

Quagrainie, K. K., Dennis, J., Coulibaly, J., Ngugi, C., & Amisah, S. (2007). Developing supply chain and group marketing systems for fish Farmers in Ghana and Kenya. *Aqua Fish Collaborative Research Support Program Technical Reports, Oregon State University, Investigations*, *2009*(2), 198-210. https://www.academia.edu/download/115049179/07mer02pu_developing_supply_chain.pdf

Ravishankar, C. N., & Elavarasan, K. (2024). Innovations in Fish Processing Technology. In *Transformation of Agri-Food Systems* (pp. 205-221). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-99-8014-7_16

Roheim, C. A., Gardiner, L., & Asche, F. (2007). Value of brands and other attributes: Hedonic analysis of retail frozen fish in the UK. *Marine Resource Economics*, *22*(3), 239-253. https://doi.org/10.1086/mre.22.3.42629557

Rondanelli, M., Rigon, C., Perna, S., Gasparri, C., Iannello, G., Akber, R., ... & Freije, A. M. (2020). Novel insights on intake of fish and prevention of sarcopenia: all reasons for an adequate consumption. *Nutrients*, *12*(2), 307. https://doi.org/10.3390/nu12020307

Rowan, N. J. (2023). The role of digital technologies in supporting and improving fishery and aquaculture across the supply chain–Quo Vadis?. *Aquaculture and Fisheries*, *8*(4), 365-374. https://doi.org/10.1016/j.aaf.2022.06.003

Sroy, S., Avallone, S., Servent, A., In, S., & Arnaud, E. (2023). Does drying preserve the nutritional quality of small freshwater fish without excessive concentrations of heavy metals?. *Current Research in Food Science*, *6*, 100489. https://doi.org/10.1016/j.crfs.2023.100489

Stevens, J. R., Newton, R. W., Tlusty, M., & Little, D. C. (2018). The rise of aquaculture by-products: Increasing food production, value, and sustainability through strategic utilisation. *Marine Policy*, *90*, 115-124. https://doi.org/10.1016/j.marpol.2017.12.027

Syanya, F. J., Mathia, W. M., Mumina, P., Litabas, J. A., & Sifuna, C. (2024). Aqua perspectives: stakeholder attitudes and perceptions in live fish transportation practices within the Kenyan fisheries sector. *Marine and Fishery Sciences (MAFIS)*, *37*(2), 317-335. https://doi.org/10.47193/mafis.3722024010507

Theuri, F. S., Mwirigi, F. M., & Namusonge, G. (2014). Determinants of value addition in the seafood industry in developing countries: An analysis of the Kenyan context. *IOSR Journal of Business and Management (IOSR-JBM) e-ISSN*, 17-25. https://doi.org/10.9790/487X-16171725

Theuri, S. F. (2015). *Strategic Management Determinants of Value Addition of Industrial Fish Processors in the Sea Food Processing Sub-Chain in Kenya*. Doctoral dissertation, Jomo Kenyatta University of Agriculture and Technology. http://ir.jkuat.ac.ke/handle/123456789/1620

TrendEconomy (2024). Annual International Trade Statistics by Country (HS).

https://trendeconomy.com/data/h2/Kenya/0304 (Accessed 12th August 2024)

Van Der Knaap, M., & Maxillion, C. (2006). An analysis of the social and economic effects of Western consumption of Nile perch from Lake Victoria. https://www.researchgate.net/profile/Martin-Van-Der-Knaap/publication/256845819_Comparative_analysis_of_fisheries_restoration_and_public_participation_in_Lake_Victoria_and_Lake_Tanganyika/links/00463530cafd32767f000000/Comparative-analysis-of-fisheries-restoration-and-public-participation-in-Lake-Victoria-and-Lake-Tanganyika.pdf (Accessed 23rd August 2024)

Wairimu, N. L. (2020). *Assessment Of The Status Of Food Control In The Informal Food Markets In Nairobi, Kenya*. Doctoral dissertation, University of Nairobi. https://erepository.uonbi.ac.ke/bitstream/handle/11295/153122/Wairimu_Assessment%20Of%20The%20Status%20Of%20Food%20Control%20In%20The%20Informal%20Food%20Markets%20In%20Nairobi%2C%20Kenya.pdf?sequence=1

Wamukota, A. (2009). The structure of marine fish marketing in Kenya: the case of Malindi and Kilifi districts. *Western Indian Ocean Journal of Marine Science*, *8*(2). https://doi.org/10.4314/wiojms.v8i2.56983

Wang, J., & Azam, W. (2024). Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers*, *15*(2), 101757. https://doi.org/10.1016/j.gsf.2023.101757