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Guidelines of Fish Supply Chain from Post Harvesting to Marketing

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ABSTRACT

This article aimed to enhance the management of the fish supply chain as a perishable commodity and to increase consumer trust. The fish supply chain begins with harvesting, whether from natural fisheries or the aquaculture sector, and extends through to marketing. It encompasses the hygienic practices of all involved parties, including suppliers, fishermen, retailers, storage facilities, distributors, transporters, and marketers. Proper hygienic handling is crucial, as inadequate practices can lead to cross-contamination at any stage of the supply chain. To improve fish quality, effective handling techniques must be applied. The use of appropriate equipment and facilities, such as cool boxes, refrigerated or insulated trucks, and boats loaded with ice, enhances the transport of fish. Improved transport methods offer several benefits to stakeholders in the fisheries sector. Consumers may be exposed to bacterial pathogens due to poor handling, washing with polluted water, or ingestion of raw or inadequately cooked fish. While most pathogens can be eliminated through adequate cooking and control measures at each stage of the supply chain, exposure to raw or undercooked fish poses a serious risk to consumer health.

INTRODUCTION

Fish have an excellent nutritional value for adult and children health and also cognitive development. Supply chain starts with the harvesting of fish mostly from natural fisheries and aquaculture sector, and finally delivering in markets to consumer. It includes suppliers, fishermen, retailers, distributors, transporters, storage facilities, delivery, and sale to the consumer **(De Silva, 2011; CWFS, 2014; Sengupta *et al.*, 2021)**. If proper good handling stages are not maintained, the microbial pollution can occur at any step of supply chain; harvesting, preparation, processing, distribution, storage and marketing **(Bouka *et al.*, 2020; Hailemichael & Gutema, 2021)**. Both long distance and difficulty tracing of fish from harvesting till consumer are major challenges that affect fish quality **(Duan *et al.*, 2020)**. In the meantime, the widespread of pathogen microbes occurs by unhygienic handling practices if fish are consumed as raw or undercooked **(Sorsa *et al.*, 2019)**. Additionally, contamination of fish with sewage and

industrial wastes and poor waste management cause chemical and biological risks that directly affect the health of the consumer **(Novoslavskij, 2016)**. Therefore, to confirm fish safety and quality and increase the consumer trust, the analytically supply chain should be practiced for all steps. In addition, the information obtained must be accurate to limit the critical control points and also to ensure fish safety and quality **(Dagninet *et al.*, 2018)**. Therefore, this article provides guidelines for the key steps in the fish supply chain to ensure high safety and quality of fishery products for consumers while reducing losses. It also addresses factors affecting fish safety and quality, including hygienic conditions for post-harvesting, handling, storage, distribution, transportation, and marketing.

2. Factors affecting fish changes

After fish harvesting, changes in sensory, autolytic enzymes, microbial activity, and lipid oxidation and hydrolysis are affected by post-mortem phase. These changes depend mainly on several factors like fish species, season, age, spawning, location, microbial load, and storage conditions. Sensory changes could be divided into three steps; pre-rigor, during rigor, and post-rigor mortis. Rigor mortis starts immediately or shortly after the death of starved fish, depleted glycogen, and/or stressed fish. The rate of rigor mortis changes varies based on fish species, size, temperature, handling, and condition of fish. The microbial activity, enzymatic and chemical reactions need an optimal temperature. If the temperature is beyond the optimal level, fish spoilage rate will be accelerated. Microbial spoilage can be classified into four categories: processing, intrinsic, extrinsic and implicit factors **(FAO, 2014; Adams *et al.*, 2016)**.

Loss of flexibility through rigor mortis after few hours after death is due to the stiffening of fish muscles **(Adebowale *et al.*, 2008)**. Degradation of most caught fish occurs due to digestive enzymes, lipase activity, and microbial contamination by surface bacteria and oxidation. Consequently, changes in odor, flavor, and texture may result from the formation of different compounds and the loss of valuable molecular components **(Baird-Parker, 2000)**.

2.1. Hazards and controlling

The physical, biological, and chemical hazards have the potential to cause harm to consumers. Some hazards may come from the catching place and nature of foodstuff **(FAO, 2011)**.

2.1.1. Physical hazards

Physical hazards include glasses, metallic, wood splinter, bones, stone, shell, plastic and fishing hooks. Other hazards may come from humans, building, equipment, and packaging materials. All these can cause adverse health effects such as choking, cuts to the mouth, throat, stomach and damage to teeth. Good hygienic practices will reduce these hazards. In some processing establishments, metal detectors may be used to screen products for metal contaminants **(FAO, 2009)**. Spoilage of fish can be controlled by reducing the temperature at all stages from delivery, during storage, till display **(Edirisinghe *et al.*, 2018)**. Temperature requirements vary among food items. Extreme

changes in temperatures leads to faster bacterial spoilage, muscle degradation, affecting both sensory and nutritional qualities, and can also cause a markedly decrease in quality and shelf life of products **(Ndraha *et al.*, 2018)**.

2.1.2. Biological hazards

Biological hazards include bacterial, viral, fungal, parasites contaminants, and fish toxicity. Pathogenic microbes may be presented throughout the place, bad handling, processing steps, and stakeholders. Poisoning can be caused by bacterial contamination, bad handling, and washing with contaminated water, which can also cause food poisoning. However, most microbes can be liminated by cooking and reduced through proper control of storage conditions **(Ames, 1990; Ames *et al.*, 1991)**.

Poor storage and bad handling of fishery products may cause the growth of spoilage bacteria such as *Lactobacillus* spp. and *Proteus* spp. **(Tahsin *et al.*, 2017)**. Microbial spoilage of fish has diverse forms in flavor, slime, gas and discoloration **(Olafsdottir *et al.*, 2005)**. Pathogenic bacteria can be divided into three groups; indigenous, enteric and bacterial contamination during processing, storage or preparation for consumption **(Elhadi, 2016)**. *Staphylococcus aureus* and *Salmonella* are more often associated with cross-contamination during production **(Svanevik, 2015)**. Pathogens bacteria like *Campylobacter, Salmonella, Yersiniaian, E. coli*, and *Listeria monocytog*en are responsible for the majority of foodborne outbreaks **(EFSA & ECDC, 2015)**. However, not all pathogens are associated with foodborne outbreaks through the consumption of contaminated fish and fishery products. Meanwhile, some bacteria species such as *L. monocytogenes, Vibrio* spp., *Salmonella, Yersinia* spp., and *C. botulinum* are widely distributed in aquatic environments and also cause high mortality rates in humans through diseases such as listeriosis, botulism, and infection caused by *V. vulnificus* **(Lindström *et al.* 2006; Lianou & Sofos 2007; Callol, 2015)**.

Some individuals can become infected by microbiological pathogens through improper handling of fish on farms, during transport via ships, or by ingesting raw or inadequately cooked products **(Austin *et al.*, 2005)**. Potential human pathogens include *Mycobacterium, Streptococcus, Clostridium, Vibrio* **(Eissa *et al.*, 2010; Agüeria *et al.*, 2018)**, as well as *Salmonella, Pseudomonas, Escherichia coli, Staphylococcus*, and *Enterococcus* **(Havelaar, 2015)**. The widespread distribution of these pathogens in aquatic environments, often due to runoff, is linked to potential water body pollution **(Callol, 2015)**. Pollution-related fishing losses account for approximately 10% of total captures and aquaculture yields **(FAO, 2010)**. Raw fish is highly perishable due to microbial activity, and the maximum acceptable microbial load is between 10^6 and 10^7cfu/ g. Fish quality deteriorates when the microbial load exceeds this range, particularly reaching 10^6 to 10^9cfu/ g which is sensory rejected **(Gram & Dalgaard, 2002; Kuuliala *et al.*, 2018)**.

2.1.3. Chemical hazards

The chemical hazards in aquatic ecosystems with potential for toxicity include pesticides, insecticides, heavy metals and industrial pollutants, contaminants (antibiotics, anaesthetics and hormones), unapproved food additives, natural toxins, mycotoxins and also various chemicals (i.e. fuel, lubricants, disinfectants and detergents) used throughout fishing and farming activity **(Obasohan, 2009)**. Fish spoilage may occur by lipid oxidation and protein degradation as well as the loss of other valuable molecules **(Ghaly *et al.*, 2010)**. In general, chemical and microbiological contaminants are responsible for losses of about 25%/year of initial agricultural and fishing **(Baird-Parker, 2000)**.

Based on the information provided, guidelines for the fish supply chain should be ascertained to ensure that fish products are healthy and to reduce losses resulting from poor hygiene practices, from harvesting to marketing.

3. Supply chain

Fish should be handled with care to avoid rigor mortis stage and reduce the physical damage. Good fish handling leads to reduced contamination, spoilage rate, foodborne illness and enhance the quality attributes through supply chain steps. However, no controlling in some factors like poor handling, temperature, and poor gutting are the most challenges. Hence, the hazard analysis critical control points system (HACCPs) should be applied to overcome or reduce these challenges. In general, the supply chain is not the only consideration. Other factors, such as the environment, personnel, boats or vessels, ice, and containers, also play crucial roles in ensuring the quality and safety of fish products. **Denham *et al.* (2015)** found that the seafood supply chain generally worked separately to improve cleaner production and grow their own businesses. The most effective strategies were unnecessary handling, energy usage, storage costs and waste production to improve the environmental performance in each phase of the supply chain. The system of supply chain management incorporated with life cycle assessment modeling is recommended to ensure the maximizing reduction in environmental impact.

3.1. Sanitation practices

The cultural practices, area conditions, processing, distribution of fish and fishery products are the main factors affecting human pathogenic microbes which are classified into two groups; natively to common freshwater habitats and related to water pollution. *Vibrio*, *Listeria*, *Salmonella*, *Clostridium*, *Listeria* and *Yersinia* spp. were found in aquaculture system **(Bottone *et al.*, 2005; Adgamov *et al.*, 2013)**. Besides, other important bacteria species can be transferred through different sources to fish causing human diseases. The environmental sanitation refers to controlling the surrounding factors which can affect human health **(EUMOFA, 2014)**. The sanitation practices could be divided into two types: poor and good sanitation practices (Figs. 1, 2).

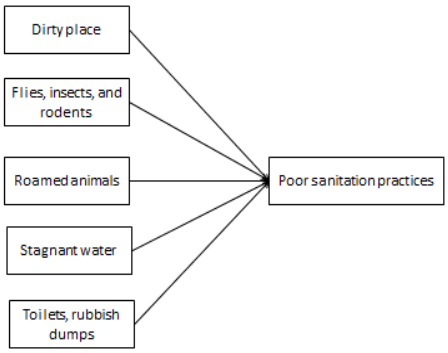

Fig. 1. Factors of poor sanitation practices

Fig. 2. Factors of good sanitation practices

Figs. (1, 2) show the factors of poor and good practices.

Source: **FAO (2014)**

3.2. Personal hygiene practices

The personal hygiene practices could be divided into poor and good factors. Poor personal hygiene practices include dirty clothes, hands and fingernails, jewelry, sickness with diarrhea, vomiting, skin infections, coughing and sneezing, failing to wash hands before and after any process, and washing hands with dirty water or without soap. On the other hand, good practices include washing hands before food preparing and handling, cleaning body and arms after eating. All these good personal hygiene practices should be adhered to regarding all the employees who are in contact with fish products **(Tibesso, 2021)**.

3.3. Fishing boats

Fishing boats should be used exclusively for catching, safety, and efficiency. They must be inspected, cleaned with chlorinated water, and dried after each use, along with all tools and equipments. Thermally insulated boxes, which should be fitted with lids and made of food-grade, smooth, easy-to-clean, durable materials, are essential for reducing potential contamination hazards **(Abate-Kassa & Peterson, 2011; Cheffo *et al.*, 2021)**. Additionally, the catch should be rinsed with running water to remove any undesirable materials.

3.4. Fish icing

Fish spoilage can be controlled by reducing the temperature at all stages till display **(Edirisinghe *et al.*, 2018)**. If the temperature is beyond the optimal level, fish spoilage rate will be accelerated as affected by microbial growth, enzymatic and chemical reaction **(FAO, 2014)**.

Fish icing is gently recommended to reduce enzymes and microbial activities, prevent dryness and loss, and to extend the shelf-life of fish. To avoid any contaminants Ice must be manufactured from drinking water or portable water under hygienic conditions and should be stored in clean containers. The icing of fish depends mainly on

fish species, season and storage conditions, and it's performed to cool the fishery products at 0°C. Flakes ice or mechanically crushed ice shapes are recommended while the ice block must be avoided **(Nicolae *et al.*, 2017)**.

The first step in fish icing involves placing a thin layer of ice at the bottom of the boxes. Then, a layer of fish should be added, followed by another thin layer of ice. This process is repeated, with layers of fish and ice up to a height of 5cm, until the boxes are filled. The boxes should then be covered with ice and tightly closed. For the finfish, it is important to replace melted ice with fresh ice at regular intervals to maintain optimal conditions. During transport from the fishing grounds to the landing site, the ice should be checked regularly to ensure that it remains constant. Precautions should be taken to account for rough weather conditions to prevent loss of catch and maintain quality **(Codex, 2020)**.

3.5. Fish harvesting

The importance of fish handling is to reduce contamination, rate spoilage, fish-borne illness and also to enhance the fish quality for processing and storage of fish. Fish should be treated with care to avoid rigor mortis effect and also physical damage of fish. Therefore, using thermally insulated boxes with lids, made from food-grade materials, helps decrease potential contamination hazards **(Abate-Kassa & Peterson, 2011; Cheffo *et al.*, 2021)**.

3.6. Losses of post-harvest fish

Nowsad (2010) estimated that fish and fishery products losses after harvesting were about 20-30% in difference, and 50% reduction. Post-harvest quality loss in wet fish ranged from 7-19%, based on different species and seasons. The previous author added that the post-harvest loss was negligible when the fish were sold to the nearer consumers within a few hours of harvest. Both fish icing quality and containers have important significant roles in reducing quality loss to 2.5%. **Nowsad *et al.* (2015)** revealed that most of the quality losses were originated at the transporters and commission agents, and estimated from 4% in the catfish to 11% in the tilapia. In case of retailer, a 16% loss was recognized in the rui and the tilapia, but 7% in the catfish and 9% in the Ilish. Higher loss was observed in fish vendors, from 10 to 19%.

There are many factors that can cause a catch loss such as traditional preservation procedures, leaving the catch for long periods in fishing gear, exposing the catch for long periods in the atmosphere, leaving fishing tools for long periods, in addition to poor storage, exposure to insects, birds, and animals, poor packaging, lack of optimal exploitation of resources, conversion of other fish into fishmeal, and also disposing of some catch having low price (they rarely used for human consumption) in the sea. All these factors lead to a huge financial loss as a result of caught spoilage **(Ames *et al.*, 1991; Yvette & Yahya, 2011)**. Post-harvest fish loss is a serious threat where fish undergoes microbiological decay; this leads to quality loss and depreciation in the market value; the consumption of such fish has adverse effects on the human health. Fishermen

need to be trained on proper handling and hygiene to ensure food safety production and improve food security. Interventions related to fisheries policies on post-harvest loss should address the future development of the fisheries sector **(Adeolu *et al.*, 2017)**.

Table 1. Summary of causes of pot-harvest loss in different steps of supply/value chain

Steps in the supply chain	Causes	Type of loss
During fishing (harvesting)	- Use of destructive/harmful methods of fishing, such as dynamite, poison resulting in harvesting fish that is already damaged or inferior quality	- Physical, quality
	- Falling from the net or discarded as by catch	- Physical
	- Entangling or enmeshing by fishing gears (nets, traps, etc.), resulting in quality deterioration and discard	- Physical, quality
	- Use of wounding gears that cause wounds and damage tissue	- Physical, quality
	- Sitting fishing gear for a long period, causing fish to spoil before the gear is hauled	- Physical, quality
Holding fish on board	- Delay in returning to landing center after fishing and exposure of fish to high temperature	- Physical, quality
	- Failure to gut (when feasible), wash and chill the fish on the boat	- Quality
	- Bulking in fish hold on board, creating heavy load on fisf that damage or deteriorate quality	- Physical, quality
	- Stepping on fish, causing physical damage	- Quality
Unloading/landing fish	- Poor hygienic practices causing contamination	- Quality
	- Fish falling from the pan/crate/basket on to the shore	- Quality, physical
	- Rough handling while unloading (throwing fish, stand on fish, etc.)	- Quality
	- Very long bargaining time at first point-of-scale, while fish kept on the ground exposed to the sun at high temperature	- Quality
	- Theft at the landing site during offloading of fish	- Physical
Immediate marketing of	- Inadequate application of ice and no insulated	- Physical

fresh fish	container used	
	- Limited preservation capacity during bumper catches for e.g. ice, ice box, processing equipment	- Physical, quality
	- Limited transport and road communication facilities during peak fishing	- Physical, quality
	- No access to or lack of marketing information with over supply of market	- Market, quality, physical
	- Deliberate delay in purchasing the fish by traders	- Quality
Processing and packaging	- Processing of already damaged/poor-quality fish	- Quality, physical
	- Processing fish under unhygienic conditions, allowing contamination (bacteria, mold) and insect infestation (blowfly, beetle, mite, etc.)	- Physical, quality
	- Inadequate control of heat intensity during smoking leads to over smoking of fish and possible burning	- Quality, physical
	- Uncontrolled processing leading to spoilage/ protein denaturation (insufficient cooking, passing air/rain water during anaerobic fermentation, etc.)	- Quality
	- Drying fish unsupervised, on grounds, sands, rocks or herbs	- Physical, quality
	- Breakage/fragmentation or damage owing to inadequate packaging methods and materials	- Quality, physical
	- Moisture reabsorption, mold attack due to inappropriate packaging	- Physical, quality
	- Oxidation of fatty fish leading to rancidity	- Quality
Storage	- Growth of mold causing spoilage, making the fish damp	- Quality
	- Insects consuming fish during storage	- Quality,
	- Discoloration owing to chemical changes	- Physical, quality
	- Inadequate storage facilities	- Quality
Distribution/transportation	- Delays owing to breakdown of transport vehicles and inaccessibility of production areas	- Quality, physical

	- Damage to fish during transportation	- physical
Marketing of fish and products	- Delays in selling	- Quality
	- Inadequate cold-storage facilities, warehouses and inadequate ice	- Quality, physical
	- Supplying the market at the "wrong time."	- Market
	- Poor purchasing power of buyers/consumers	- Market

Source: **FAO (2021)**.

Appropriate harvesting and rapid processing should be applied to minimize physical damage and stress. Fish should be washed carefully with clean water at suitable pressure, gutted, and handled properly to avoid exposure to extreme heat, cold, or improper salinity, which can reduce contamination. Equipment and holding tools should be easy to clean and disinfect **(Codex, 2020)**. **Montojo *et al.* (2020)** reported that ice-chilled carrier boats from High Seas Pocket 1 (HSP-1) experienced an estimated loss of 17.25% (USD 4.3 million), with low-quality catch contributing to these losses. There was a positive correlation between fishing duration and losses, as the preservation techniques on these boats led to fish quality deterioration over long distances and transit times. Therefore, allowing the use of carrier boats equipped with freezing systems in HSP-1 could better preserve the quality of the catch and reduce post-harvest losses, thus increasing potential income.

The average post-harvest loss was found to be 11.67% for marine fish, 7.01% for captured fish, and 4.47% for cultured fish. To minimize these losses and enhance the contribution of the fisheries sector in Bangladesh, government and fisheries agencies should promote initiatives, practices, and policies that address post-harvest loss **(Rashid & Kabir Sarkar, 2020)**. The causes of post-harvest loss at different steps of the supply/value chain are summarized in Table (1).

CONCLUSION

In conclusion, fish represent a highly perishable product due to their chemical composition. The fish caught are exposed to various risks—physical, chemical, and biological—arising from environmental factors, tools, personnel, and inappropriate conditions. These risks can negatively impact both the quality of the fish and human health. Therefore, effective management throughout the entire supply chain, from fishing to consumption, is essential to ensure safety and high quality, achieving the goals of a well-functioning supply chain.

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