of fish is caused by many reasons such as poor handling and preservation or discarding of bycatch. Economic losses happen when spoilage of wet fish leads to the decrease in value or when there is a need to reprocess cured fish resulting in a raised cost of the finished product. Additionally, inadequate handling and processing methods can also lead to reduced nutrients and nutritional losses. Hence, the conversion of large quantities of fish catches into animal feeds can be considered as a "loss" to human food security.

In the Southeast Asian region, the volume of low-value fish catch depends on the fishing season, fishing grounds, and fishers' efforts in sorting out the catch. Low-value fishes are grouped into those of deteriorating quality unsuitable for human consumption, which is used to produce feeds, and low-value small-sized fish, which are acceptable for human consumption. The quality of fish tends to deteriorate due to poor methods and unavailability of facilities to preserve fish onboard fishing vessels as well as the long period spent at sea.

Thus, it is of utmost importance that fish catches are utilized responsibly and post-harvest losses are minimized to attain food security for the Southeast Asian region. SEAFDEC/MFRD has conducted post-harvest projects on small pelagic marine and freshwater species in the region to maximize utilization by collaborating with the National Centre for Quality Control and Product Development (NCQC) of Indonesia to examine the utilization of small pelagic fish species, and with the Fisheries Administration (FiA) of Cambodia for the utilization of freshwater fish catch.

SEAFDEC/MFRD has conducted several activities that include the utilization of underutilized marine and freshwater fish species for the development of surimi and value-added fish products to produce fish jelly products such as fish balls and cakes, which are popular traditional products in the Southeast Asian region. The development of the surimi industry has offered markets to what was considered before as low-value fishes. Fish species such as threadfin bream, lizard fish, big-eye snapper, croaker, and goatfish or red mullet are often regarded as being of low economic value due to poor consumer preference and poor quality, but their usage in the surimi industry had indicated their importance in producing value-added products for human consumption such as fish sausage, fish burger, fish tofu, fish floss, fish siew mai, and many others.

A project on the utilization of low-value freshwater fish species was carried out in Cambodia in collaboration with FiA. Three fish species that are considered low-value and underutilized, namely: featherback fish (*Notopterus* spp.), snakehead fish (*Channa* spp.), and soldier river barbs (*Cyclocheilichthys enplos*), are used in the study. The results had allowed the development of a new range of value-added fish products from these underutilized freshwater fishes and helped to promote the conversion of underutilized freshwater fishes for human consumption while also improving the socioeconomic conditions of people dependent on freshwater fisheries. Featherback and snakehead fishes are used to produce fish bak kwa, fish cracker, fish siew mai, and fish tofu, while soldier river barbs are utilized to produce snacks such as fish muruku and fish satay.

These technological approaches have allowed the maximum utilization of fishery products, ranging from low-value small demersal and pelagic fish species to underutilized freshwater species, and the technology would be transferred to the AMSs. These value-adding technologies have also helped to minimize wastage and losses, thus contributing to food security and the economy of the AMSs.

5.1.2 Management of Food Losses and Wastes

Food loss is defined as any food that is lost in the supply chain between the producer and the market that leads to a decrease in the quantity or quality of the food. Food waste is defined as a safe and nutritious food that is discarded, whether by choice or due to spoilage as a result of negligence. As the global population is projected to grow to 9.7 billion by 2050, there are concerns that food production will be unable to keep up with rising demand. By minimizing food losses and wastage, improvements to food security could be achieved as this would ensure that more food is available instead of being lost or wasted throughout the supply chain. The impact of food loss and waste vary widely among the AMSs, so as the management strategies employed to reduce food losses and wastage (**Box 15**).

Box 15. Management strategies employed by some AMSs to reduce food loss and waste

Indonesia: The country has measured or estimated the quantities of food loss and waste across the fishery supply chain using the methodology of Food Loss on Production and Harvest Phase, Handling Phase, Storage Phase, Processing and Packaging Phase, Distribution and Marketing Phase, and Food Loss on Fishery Products during Household Consumption. Areas where food loss and waste occur are spread throughout the supply chain. During production, fish may be damaged due to inadequate cooling processes or facilities while on board or death due to weather changes, water upwelling, and water pollution. During postharvest, fish loss may occur due to damage during handling after unloading and storage, by pests or predators, or spoiling of fish that were not sold as they were stored for too long. For processing, less-skilled workers may cause higher wastage of fish parts when carrying out separation of flesh from the bones and skin, and limited waste utilization technology *e.g.* utilization of shrimp shell waste into chitin/chitosan, the process of utilizing fish canning industry waste (fish oil) is also a restricting factor. For distribution, excess supply of fish and shortage of buyers led to unsold products being wasted, and products may also be damaged due to delays in distribution/transportation, poor packaging, improper handling, and inadequate facilities and infrastructure. Retailer product quality standards may also make it difficult for fish farmers to supply products to the market. Food waste occurs at the consumption stage due to products with non-standard packaging that are wasted, and food thrown away in households and food providers such as restaurants and catering services. Currently, interventions to minimize food loss and waste along the food supply chain are being implemented. In the processing supply chain segment, there are measures such as by-product utilization training, post-harvest facilities assistance, development of cold storage and integrated cold storage, regulation on Increasing Value Added of Fishery Products as well as implementation of Miniplant Zero Waste Development Program. For reducing food loss and waste during distribution, Indonesia has initiated support programs for the Provision of a Cold Chain System, which includes construction of a portable frozen warehouse for fish storage, procurement of refrigerated cars/trucks for the distribution of frozen and fresh fish and procurement of ice making machines (blocks or flakes) as a cooling medium for the sale or marketing of fish to consumers or buyers, in order to maintain the quality of fish. Additionally, the Guidance for Handling in the Distribution of Fishery Products has been published to support local fishery industry. In the area of consumption, measures for reducing food loss and waste in Indonesia include educating consumers to avoid over-buying, for example purchasing large quantities of foodstuffs that are not required to be used immediately, and giving consumers a better understanding of the difference between "best before" and "best by" dates. In addition, consumers can implement better storage practices and stock management at home, and better evaluate portion size to be appropriate. Improved food preparation techniques that will maximize utilization of food and prevent deterioration of food quality should also be adopted. Finally, utilization of leftovers in recipes rather than throwing them away should also be done.

Malaysia: Generally, the fish supply chain consists of the following main phases, namely: harvest/production, sorting, chilling/freezing, packaging, storage, transportation, and market/consumer (domestic/export). The critical stages of the supply chain segment where food loss and waste occur most are at the harvesting and market/consumer phases. To minimize food loss and waste in the fishery supply chain, Malaysia has implemented interventions and measures, which include those for the production supply chain phase, where measures such as encouraging the use of efficient technologies, improving fishing vessel storage facilities, implementing traceability systems, and building capacity by developing expertise and conducting training, are being carried out. The implementation of Good Manufacturing Practice (GMP), monitoring programs such as the Hygiene on Board (HOB) program, and developing the Malaysian Standard of Hygiene on Board (MSHOB) to enhance the willingness of local vessels in practicing proper fish handling procedures, also serves to reduce food loss. For processing, the use of efficient technologies, implementation of traceability systems, certification programs such as GMP and HACCP as well as capacity building of fish workers, contribute to reducing food loss. During distribution, the use of better packaging and temperature-controlled storage of products in properly equipped transportation also decreases the amount of fish lost during this stage. Finally, awareness program and campaign conducted on consumers helped to reduce food waste at the consumption stage.

Philippines: Food waste and loss occur across the different stages of the supply chain. During the production stage such as fish capture or harvesting of farmed fish, inappropriate postharvest handling may result in food loss. Onboard fishing vessels, undersized or non-valuable fish are discarded. During processing, non-compliance to cold chain and inappropriate processing and preservation conditions also contribute to food loss. Inappropriate transport and distribution facilities during distribution as well as inappropriate handling and preparation techniques by consumers also lead to food loss and waste of fish and fishery products. Under the Comprehensive National Fisheries Industry Development Plan launched in 2016, the country aims to reduce fisheries postharvest losses from 25 % to 15 % (Department of Agriculture, 2016). This would be achieved by the setting up of Community Fish Landing Centers (CFLCs) in strategic coastal communities which could provide postharvest facilities and give more fishers access to ice-making facilities to reduce food loss due to inappropriate storage temperatures. Other facilities such as fish stalls, air blast freezers, ice plants and cold storage facilities, refrigerated vans, solar driers/smokehouses, and warehouses would also be provided. Furthermore, the utilization of fishery by-products to produce new products has also been gaining popularity. Some examples of such products include dietary supplements that include calcium from the backbones, fins, and offal of several fish species as well as shrimp flavor concentrate from shrimp heads that are dried and processed, and are used as base for the commercially available shrimp flavors sold either as cubes, bouillons, or powdered additives.

Singapore: A study by the Singapore Environment Council published in 2019 estimated that 25,000 mt of fish and seafood are lost per year in Singapore. This figure accounts for both local production of food and imported food landings. The study's methodology consisted of interviews with key stakeholders in the food supply chain in Singapore, including farmers, importers, distributors, retailers, waste management experts, academicians, and non-profit organizations, as well as literature review of past studies focusing on food loss and waste conducted globally and in Singapore. Food loss and waste occur throughout the food supply chain. During the primary production of fishes, food loss and waste can be caused by several factors including disease, poor water quality, and poor post-harvest handling. For midstream processes such as processing, packaging, and distribution, incorrect freezing process can lead to a loss of quality during frozen storage. Frozen products can suffer from "freezer burn" and are more susceptible to damage by rough handling. Losses in fish also occur during processing, such as canning or smoking, where trimming spillage are thrown away. Food loss during retail and consumption can be caused by oversupply of fish and seafood resulting in food loss if they are left unsold. Inadequate consumer knowledge of proper storage and management of food purchases could also result in food spoilage and wastage. To minimize food loss and waste in the fishery supply chain, Singapore has implemented numerous measures. For production, climate resilient and sustainable aquaculture technologies have been developed which will minimize food loss. For example, real-time water quality monitoring systems had been incorporated into coastal fish farms that serves to alert the farmers during poor water quality conditions (*e.g.* when there is low dissolved oxygen). Floating closed containment systems, whereby fishes are reared in a controlled environment to protect them from adverse conditions have been developed as well. For processing, the National Environment Agency (NEA) of Singapore launched the Food Resource Valorisation Awards in 2021 (NEA, 2021), which aims ...

Box 15. Management strategies employed by some AMSs to reduce food loss and waste *(Cont'd)*

... to recognize the efforts of companies that adopt food waste valorization solutions as well as raise awareness of the concept. Through this award, Singapore seeks to encourage more organizations to adopt and develop similar food waste valorization solutions by recognizing companies that engage in the conversion of food waste, such as homogenous by-products, rejects, and mixed food waste into products that contribute to a sustainable economy. One example of waste valorization in Singapore's fishery supply chain is the use of grey mullet offcuts (head, bones, and trimmings left after processing into fillets) to make soup (Tan & Liu, 2020). In the area of distribution, Singapore minimizes food loss and waste by requiring food establishments to employ appropriate cold chain requirements to ensure food safety, as part of the licensing requirements. To assist the industry, the new Singapore Standards for Cold Chain Management of Chilled and Frozen Food to Assure Food Safety and Quality was published in October 2021 with the intention to strengthen cold chain ecosystem by setting out the General Requirement and Code of Practice for management of chilled and frozen food including seafood. The guide on Good Handling Practices and Cold Chain Guide for Chilled Seafood was also developed by the Singapore Food Agency (SFA) which includes guidelines on temperature control, processing and packaging, transportation, and display for sale to ensure the quality and safety of chilled fish and seafood to minimize losses. An example of this implementation is the e-commerce retailer Redmart which delivers fresh produce to consumers by utilizing normal delivery trucks, but the trucks are lined with reusable insulation and industry-grade ice plates that can be refrozen after each use to maintain the optimum temperature (Neo, 2019). This maintains the cold chain process during delivery and reduces potential food loss when delivered to consumers. For consumption stage, the Food Waste Reduction outreach program in 2015 of NEA aimed at encouraging the adoption of smart food purchase, storage, and preparation habits, helps consumers save money while reducing food wastage at source (NEA, 2020). Educational materials have been publicized on print and social media platforms, and Food Waste Minimisation Guidebooks were published in 2017 for food retail establishments, supermarkets, and food manufacturing establishments to reduce food waste across the supply chain.

Thailand: Majority of fish catch of the country is intended for human consumption, and the remainder is mainly utilized to produce feeds and fertilizer. Higher quality fish are used for human consumption while lower quality fish are used to produce feeds, and fish of the lowest quality are used for fertilizer. Since all parts of fish are utilized to produce either food or non-food products, there is rarely food loss and waste in the fishery supply chain. Nonetheless, the key stage that generates the most food loss is postharvest after production and before processing due to ignorance of low temperature control during handling. To minimize food loss and waste in the fishery supply chain, the country has invested in automation process and use of traceability systems during production stage. For processing, traceability systems are also being implemented. For distribution, better logistics and transportation, packaging, and usage of information technology to monitor temperature during distribution, are meant to reduce food loss. For consumption, educated retailers and consumers, and higher consumer awareness have helped to reduce food waste.

Viet Nam: Under Resolution 48/2009/ NQ-CP, the government set the target of reducing the rate of aquaculture postharvest losses from 20 % to 10 % in 2020 (APEC, 2018). This target would be achieved through building aquaculture ponds equipped with advanced equipment to limit risks caused by environmental impacts such as weather and epidemics, and improvement of freezing preservation technology (Ministry of Agriculture and Rural Development, 2009). In addition, the government has also enacted a policy to provide financial incentives for businesses, farmer cooperatives, and farmers for investment in agricultural facilities such as freezers to reduce postharvest losses.

5.1.3 Food Safety from Marine Biotoxins

Potential hazards in aquaculture can be broadly classified into biological hazards and chemical hazards. Common biological hazards are bacterial pathogens (*e.g. Salmonella* spp., *Shigella* spp., *Vibro* spp., listeria monocytogenes, and pathogenic strains of *Escherichia coli*), parasites (*e.g.* trematodiasis, cestodiasis, and nematodiasis), and viruses (*e.g.* Norovirus, Hepatitis A virus). The primary chemical hazards for aquaculture products include veterinary drug residues, agri-chemicals (*e.g.* pesticides, herbicides, fungicides, disinfectants), heavy metals, persistent environmental contaminants (*e.g.* organochlorine compounds like PCBs and dioxins), and naturally occurring biotoxins (*e.g.* marine biotoxins, scombrotoxins). These hazards are usually associated with the farming system and management, aquaculture habitats and practices, the species being farmed or caught, environmental conditions of the farming sites, and cultural habits of food preparation and consumption. Control measures have been established to address the potential risk from marine biotoxins and scombrotoxins in the context of intensifying climate change, growing population, and wide-spreading environmental pollution.

Over the recent decades, increasing eutrophication, warmer seas, ocean acidification, and food web modifications resulting from overfishing and other factors, have led to increased prevalence of harmful algal blooms (HABs) globally. These algal species can be broadly classified into microalgae (unicellular organisms) and macroalgae (multicellular, also called seaweeds), and together they produce more than half of the oxygen in the earth's atmosphere. The occurrence of algal blooms denotes an increase in the abundance of a single (or more) algal species in each area and the growth reaches bloom proportions when a series of environmental factors occur in synchrony—temperature, salinity, light, turbulence, availability of micro- or macronutrients, availability of trace elements, and in the case of microalgae, interactions with populations of marine bacteria, viruses, and algal grazers. Moreover, a growing interest in increasing aquaculture and mariculture facilities to meet the increasing demand for food has brought with it significant food safety concerns related to phycotoxins caused by the proliferation of HAB species, as consumption of seafood and fish is the primary route for exposure to phycotoxins (algal toxins) in humans. HAB phycotoxins may bioaccumulate in fish and shellfish that can induce toxic syndromes in humans who consume them, with symptoms ranging from skin, eye, or ear irritations to more severe reactions such as liver and kidney damage and gastrointestinal, cardiovascular, respiratory, and neurological conditions.