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INNOVATIVE PROCESSING TECHNOLOGIES FOR SUSTAINABLE FISHERIES SECTORS

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Abstract: Fish and fishery products are important food commodities that benefit human health, offer high commercial value and contain high protein, vitamins, minerals and unsaturated fatty acids. High demand and mass commercialisation of fish and fishery product regulate the international seafood business. Subsequently harvesting, the fish and fishery product face multiple supply chains and time in marketing and distribution to reach consumers. Therefore, these may lead to biodeterioration and thus require proper and innovative processing technologies for fish and fishery products preservation and shelf life extension. These include chilling, freezing, drying, freeze drying, smoking, vacuum packaging, modified atmosphere packaging, canning, irradiation, high-pressure processing and using natural products as preservative agents. Innovative processing technologies are important and contribute to sustainable fisheries management, supply chain and local and international trade.

Keywords: processing, innovative, sustainable, fisheries, fish quality.

Introduction

The fishery industry has emerged since 1948, with fish capture at approximately 22 million tonnes harvested (Oehlenschlager & Rehbein, 2009). Food and Agriculture Organization (FAO, 2020) reported that in 2020, world total fisheries and aquaculture production had increased to 214 million tonnes, of which 178 million tonnes contributed from aquatic animals and 36 million tonnes from aquatic botany. However, with the impacts of the COVID-19 pandemic, capture fisheries recorded a decline of 4.4% in 2019 compared to the previous year to give a record of 90.3 million tonnes but remain stable globally. Meanwhile, global aquaculture was recorded at 123.3 million tonnes, which consists of about 87.5 million tonnes of aquatic animals, 35.1 million tonnes of seaweed and other algae and approximately 700 tonnes of shells and pearls (FAO, 2020).

The fisheries and aquaculture sector contribute to the Sustainable Development Goals (SDG), especially SDG14 Life below water - Conserve and sustainably use the oceans, seas and marine resources for sustainable development. SDG14 is important for global food security and nutrition. The fisheries and aquaculture sectors are significant to environmental, social and economic sustainability, reducing the ecosystem impacts, ensuring social equality and responding the climate change. FAO (2020) documented that 600 million livelihoods depend on employment in primary, along the value chain and post-harvest activities. Governance frameworks, technological innovations, investment opportunities and value chain developments are required to expand the sustainable fisheries and aquaculture sector. Moreover, effective fisheries management and rejuvenation of the exploited resources will support social outcomes, encourage equitable livelihoods and ensure resources and services among small producers. In addition, upgrading the value chain will significantly benefit the consumers, minimise the postharvest loss, develop traceability and boost the lucrative markets. This review intends to summarise the application of innovative seafood processing technologies has potential benefits for sustainable fisheries sectors.

Nutritional Benefits and Composition

A survey by the FAO (2020) reported that the total fish consumption of the global population approximately consists of 17% animal protein, which is 7% of all proteins consumed. In industrialised and developed countries, fish consumption was 26.8 kg and 24.4 kg per capita in 2017, respectively. Meanwhile, 19.4 kg and 12.6 kg per capita of fish were consumed in developing and least-developed countries. FAO (2020) also documented an increase of 1.5% in fish consumption rate annually for low-income food-deficit countries to 9.3 kg per capita in 2017, since 1961 (only recorded 4.0 kg per capita). The Scientific Advisory Committee on Nutrition (SACN, 2004) proposed that two portions of fish consumption per week, which are one portion of oily fish and one portion of white fish are essential to ensure the diet contains the equivalent of approximately 0.45 g long chain n-3 polyunsaturated fatty acids (PUFAs) per day. Fish generally is a good source of several nutrients and contributes on average one-quarter of the recommended intake of vitamins D, B_{12}, and selenium (Avenell *et al.,* 2006).

The fish's nutritional composition is similar to the land animals. Fish have high water content, ranging from 66 to 84% (Huss, 1989). Generally, fish constitute protein, 15-24%; lipids, 0.1-22.0%, and vitamins and minerals, 0.8-2.0% (Huss, 1989). The oxygen supply in fish tissues decreased spontaneously and established the anaerobic metabolism right after fish death. Both anaerobic sources of adenosine triphosphate (ATP), creatine phosphate and anaerobic glycolysis decreased rapidly and led to the depletion of energy resources in the muscle. Gill (2000) reported that when ATP level reaches its minimum of 1-2 µmol per g tissue, an irreversible interconnection of myosin and actin leads to actomyosin formation. Thus, fish muscles become stiff due to the Ca^{2+} ions accumulation inside the cell indicating the failure of the calcium pump in the sarcoplasmic reticulum (Gill, 2000). The skeletal muscle stiffening after death is known as the *rigour mortis* phenomenon.

Fish Quality

The appearance and freshness of the fillet have a significant effect on the quality of the fish. Fish is fresh at the *pre-rigour* or *rigour* phase. The processes of biochemical and biophysical involved during the *rigour* phase influence the appearance of the fillet due to the direct response to ATP degradation (Brogstrom, 1961; Hong *et al.,* 2017; Karim *et al.,* 2019). Both ATP and ADP disappeared after 24 h of death. These changes are autolytic and allow the proliferation of spoilage microorganisms. Nucleotides mainly inosine monophosphate (IMP) are recognised as important contributors to the flavour of good quality fish. The degradation of IMP subsequently produces hypoxanthine (Hx) (Howgate, 2005). In addition, hypoxanthine is a well-known chemical indicator of fish freshness and quality. Meanwhile, ATP degradation to IMP is attributed to endogenous autolytic enzyme activity (Gram & Huss, 1996), whereas the IMP breakdown to Hx is caused by both enzyme and microorganism activities (Karim *et al.,* 2019).

Spoilage odours from chilled fish vary depending on the dominant microflora. The presence of bacteria from the genera *Enterobacteriaceae, Alteromonas/Shewanella, Photobacterium, Pseudomonas* and *Vibrio* (Huss, 1995; Dalgaard, 2000; Gram & Dalgaard, 2002) is associated with trimethylamine (TMA) accumulation. TMA is a typical and major contributor to fishy odours, which can be overpowering as their concentration increases during storage (Olafsdottir & Jonsdottir, 2010). Lipid oxidation contributes to the development of rancidity due to the production of odorous carbonyl compounds produced by the oxidation of polyunsaturated fatty acids. These smells are perceived as earthy, cucumber and mushroom-like (Olafsdottir *et al.,* 1997) or musty, mouse-like, stale, cabbage-like and turpiny, as mentioned by Siroszki *et al.* (1990). In addition, lipid oxidation may also alter fish colour in dark-fleshed fatty fish due to the transition of myoglobin to metmyoglobin.

Innovative Seafood Processing Technologies

Post-harvest handling, hygiene standards during handling, processing and storage, environmental factors and preservation parameters are important for keeping the fish quality. In addition, preliminary processing is significant to maintain quality, meet further processing needs, and meet consumer approval. Preliminary processing also allows for efficient utilisation of inedible parts for animal feed production, prolongs the shelf-life of fish by isolating the edible perishable parts early and maximises economic use of raw materials. Moreover, recent and emerging technologies offered a shelf-life extension and improved the sensory properties of the product. The main purpose of innovative processing technologies is to stop or slow down spoilage and maintain freshness. Emerging technologies can prevent bacterial growth, retard fat oxidation and inhibit the natural ageing process and discolouration. Innovative seafood processing technologies include chilling, freezing, drying, freeze drying, smoking, vacuum packaging, modified atmosphere packaging, canning, irradiation, high-pressure processing and using natural products as preservative agents.

Sustainable Fisheries, Value Chains and Trade

Innovative processing technologies are significantly important and contribute to the sustainable fisheries sectors. Innovative processing technologies help to ensure sustainable fisheries management by creating and implementing local and international strategies for sustainability, preservation and protection of fisheries and ocean health through technical assistance and technology transfer, especially for small-scale and artisanal fisheries. In addition, up-scaling successful products and providing market access to small-scale and artisanal fisheries promise economic benefits to livelihoods. Chiller and freezer are the most common and important innovative processing technologies widely used along the value chain. These facilities are the best practice for the upstream and downstream activities immediately after harvesting, value addition in processing and distribution and other post-harvest activities. This also is an extension to benefit the employment and economic value for countries in general and local coastal communities involved in downstream activities.

Innovative processing technologies contribute to restoring the productive capacity of the oceans and increase the economic benefits to developed countries. The Ocean or Blue economy refers to the combination of socio-economic development from environmental degradation (UNCTAD, 2019) with a focus on the gender, poverty and vulnerable groups undertaking to integrate environmental protection, economic development and social responsibility. Supply and value chain analysis may benefit the development of the Ocean economy by focusing on efficient logistics and supporting services using upstream and downstream businesses. A long variation of the supply chain in the fisheries industry may involve innovative processing technologies such as cold stores and ice making at fishing ports, primary (cold water immersion and individual quality freezing (IQF) on fish fillets) and secondary (cooked, grilled, fried, breaded, marinated) production in the processing plant and cold transportation during distribution and sales.

Innovative processing technologies also benefit the supply and demand for traded food commodities. In achieving the trade related to SDG14, innovative processing technologies give the advantage of enlarging the Exclusive Economic Zones (EEZ) and economic value. FAO (2020) documented that more than 200 countries are involved in imports and fisheries products and exports. China leads as the main exporter and world fish producer, followed by Norway and Vietnam. Meanwhile, the European Union (EU) is the most importer of fish and fish products followed by the United States of America and Japan. Therefore, the seafood trade will encourage a broader fish species choice and consumption among consumers worldwide. Moreover, innovative processing technologies

also meet the rapid changes in consumption habits and consumer preferences in preparing, processing, marketing and distributing fish and fish products. The intermixing of these drivers of change has been multidirectional and complex and the pace of transformation is relatively rapid. Thus, global per capita fish consumption continues to rise and diversifies up to 88% from 67% in the 1960s.

Strong policy recommendations by the governments, Non-government Organisations (NGOs) and private sectors play an important role in equitable distribution among small-scale fishermen and aquaculture farmers for dignified livelihoods commensurate to their key role in fisheries sustainability. Moreover, technical training, infrastructure and facilities improvement, finance and research and development on international trade requirements and certification and hygiene practice are the key factors in achieving the trade-related targets of SDG14. Eco-labelling and certification that provide for the fish and fish products that meet the local and international trade requirements positively affect local food security, preserve the fisheries resources and sustain international trade in the long term.

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