CHAPTER 2

Fishery Industry Waste: A Resource to Be Valorised

Toms C. Joseph*, Remya. S, Renuka. V, and Ashish Kumar Jha
Veraval Research Centre of ICAR-CIFT, Veraval, Gujarat
*E-mail ID: tomscjoseph@gmail.com

Introduction

Seafood species are nutritious since they are rich in proteins and other nutrients including peptides, essential amino acids, long-chain omega-3 polyunsaturated fatty acids, carotenoids, vitamins including vitamin B_{12}, and minerals such as calcium, copper, zinc, sodium, potassium, selenium, iodine etc. Fish processing operations result in production of solid wastes in the form of fish carcasses, viscera, skin and heads and liquid wastes including washing and cleaning water discharges, blood water from drained fish storage tanks, brine etc. The magnitude of the problem of waste management in the fish industry depends on the waste volume, its polluting charge, rate of discharge and the assimilatory capacity of the receiving medium. About 30 % of the total fish weight remains as waste in the form of skins and bones during the preparation of fish fillets and these are generally dumped into land or hauled into the ocean. This waste is an excellent raw material for the preparation of high value products including protein foods. Fish processing generates a huge amount of solid wastes that can be as high as 50-80 % of the original raw material. As a result, every year a considerable amount of total catch is discarded as processing leftovers. Though some of the by-products are utilized, the main bulk is dumped to waste creating both disposal and pollution problems.

Probably, more than 50 % of the remaining material from the total fish capture is not used as food and involves almost 32 million tonnes of waste. India alone generates greater than 2 million metric tonnes of waste due to fish processing activities. The maximum waste was generated during processing of shrimps, followed by fin fishes and cephalopods. The various pre-processing operations involve beheading, skinning, gutting, de-scaling, filleting, etc. Processing discards are as high as 40 % of whole shrimp and krill, 50 % of crab, and 24 % of squid. The fish waste is considered as worthless garbage and is generally discarded without recovery of any useful product. The organic components of the waste have a high biological oxygen demand and if not managed properly, can pose environmental problems. Adverse environmental effects associated with seafood processing waste discharges include, accumulations of the waste sludge and whole fish parts in near-shore locations, generation of toxic hydrogen sulfide gas, increased gathering of scavengers in discharge locations, noxious conditions caused by odours, bacteria and waste decomposition. In the last two decades, there has been a global awareness of the environmental, economic, and social impacts of fish processing, calling for efficient utilization of the discards. In response to that, research has been carried out throughout the world to develop methods to convert these wastes into useful products.

Animal Feed

Nowadays, the use of food wastes as animal feed is an alternative of high interest, because it stands for environmental and public benefit, besides reducing the cost of animal rearing. Offal from the fishing industry could be used as a feed ingredient, as it represents a valuable source of high-quality protein and energy. Fish meal is the most important product obtained from fish waste. It is highly concentrated dry nutritious feed supplement consisting of high-quality protein (70 %), minerals (10 %), fat (9 %) and water (8 %). It can have different compositions and qualities, in terms of amino acid profile, digestibility, and palatability, depending on the raw material used for its production and the type of process employed for obtaining the meal. Fish meal is mostly used as an ingredient in feed for fish and crustaceans. Differences in fish meal quality can affect the growth and feed efficiency ratios of the organisms fed. Fresh raw material and stale raw material can produce significant differences in the content of biogenic amines such as cadaverine in the fish meal and high-quality fish meal with low biogenic amine content. These differences affect certain nutritionally important parameters in the organisms fed with those particular fish meals, such as feed intake and feed efficiency, both being reduced in the case of the poor quality fish meal. The fish meal can be produced by two general processes like dry rendering and wet rendering. Process conditions also affect the meal quality.

Fish Silage

Viscera of fish including the digestive tissues and other organs like spleen and gonads can be used to obtain fish silage. Almost any low-cost species of fish can be used to make silage, though cartilaginous species like sharks and rays liquefy slowly. Fish silage can be defined as a product made from whole fish or parts of the fish to which no other material has been added other than an acid and in which liquefaction of the fish is brought about by enzymes already present in the fish. The rate at which the liquefaction takes place depends upon the temperature and pH of the mixture. Fatty fish liquefy more rapidly than white fish and fresh fish liquefy more rapidly than stale fish and previously chilled or frozen fish. Since the nutritional value fish diet is determined basically by the amino acid composition of the feed, it is concluded that silages made from fish waste materials are adequate for use as an ingredient in balanced diets. So, the ensilage can be used as for fish meal replacement for the production of feeds.

Fish Protein Hydrolysate (FPH)

FPH is a liquefied product but different from silage. FPH may be defined as fish proteins that are broken down into peptides of various sizes. These products are produced by employing commercially available proteolytic enzymes for isolation of enzymes from fish waste. By selection of suitable enzymes and controlling the hydrolysis conditions, properties of the end product can be selected. Hydrolysates find application in milk replacers and food flavourings. According to the WHO's recommendation, fish protein also serves as a significant source of essential amino acids (about 30 % by weight). That is the reason why fish protein hydrolysates are becoming more popular. The degradation can be carried out either chemically (using acid or alkali) or biologically (using enzymes). Such processes not only maintain a high essential amino acid content but also generate many improved functions for food or pharmaceutical application. Similarly, natural anti-oxidants like FPH could be used for improved anti-oxidation and anti-hypertension activities and to control high blood pressure, in addition, to replace synthetic products, which may have negative side effects. So, the production of fish hydrolysate from fish processing waste will reduce the pollution due to the accumulation of fish waste in the environment from the fishery based industries. Most hydrolysates are bitter in taste after the time of production. Therefore, flavouring agents like cocoa and sugar should be used during the fortification in food preparation to mask the bitter taste.

Fish Oil

Fish oils can be extracted from the whole fish, skin or liver. Fish oils are rich sources of polyunsaturated fatty acids, especially Eicosapentaenoic acid (EPA) and Docosa hexanoic acid (DHA). These two compounds have shown different interesting bioactivities. Among the properties of omega-3 fatty acids, the best known are the prevention of atherosclerosis, reduction of blood pressure and protection against arrhythmias. Squalene is a lipid found in large quantities in shark liver oil. The large by-catch of shark in the fishing industry around the world provides a useful source of fish oils, whose value can be substantially increased by processing them to obtain fractions such as squalene. Squalene is interesting bio-active oil and their applications have been reported in the treatment of diabetes, cancer, and tuberculosis. It also has antifungal and antioxidative properties.

Collagen and Gelatin

Skin, bones, and fins represent around 30 % of fish fillet processing waste and are produced as a consequence of the preparation of different fishery products such as fillets and sashimi (sliced raw fresh fish). Fish skin, therefore, is an important by-product of the fish-processing industry, causing wastage and pollution. Collagen is the major structural protein found in the skin and bones of animals and gelatines are their degradation products. The collagen obtained has potential use for a variety of applications like edible casings for the meat processing industries, cosmetics (because of its good moisturizing properties) and biomedical materials or pharmaceutical applications, which include the production of wound dressings, vitreous implants or carriers for drug delivery. Some reports also show that collagen may evince high anti-radical activity. It is well established that the amount of gelatin used in the food industry worldwide is increasing annually. It has been also demonstrated that fish gelatin can stabilize emulsions, remaining moderately stable to droplet aggregation and creaming, even after being subjected to changes in temperature, salt concentration, and pH. Gelatin from marine source can be a possible alternative to bovine gelatin in future days.

Biodiesel

Biodiesel is comprised of monoalkyl esters of vegetable oils, animal fats or fish oils, which can be synthesized from edible, non-edible and waste oils. It is a non-toxic, biodegradable and renewable energy source. Biodiesel can be produced chemically or enzymatically. Currently, the biodiesel production on an industrial scale is being carried out chemically, using alkali (NaOH) as catalyst due to high conversion ratio of triglycerols (TAG) to methyl esters (biodiesel) and low reaction times (4-10 h). There are several disadvantages using chemical catalysts including high reaction temperature, soap formation, waste generation and contamination of glycerol with alkali catalysts.

Pigments

Valuable pigments have been found in a variety of fish raw materials, especially in seafood waste. Various studies have reported the presence and recovery of pigments such as astaxanthin and its esters, b-carotene, lutein, astacene, canthaxanthin and zeaxanthin in crustacean waste. Carotenoids are a group of fat-soluble pigments that can be found in many plants, algae, microorganisms, and animals, and are responsible for the colour of several shellfish. Carotenoids have been extracted using shrimp waste, from processing head and shell of shrimp, applying different organic solvents. Carotenoids were also extracted from fish eggs and from fish scales waste also. These valuable pigments would be cheaper alternative applicable to a wide variety of industrial needs such as colouration of some surimi-based products or aquaculture feed formulation. Furthermore, some pigments like astaxanthin are important in medical and biomedical applications due to their high antioxidative effects and to the fact that they are precursors of vitamin A.

Chitin and Chitosan

Chitin, a polysaccharide and one of the major components of crustacean shell waste, has been found to be a potential source of antimicrobial substances, due to the high percentage that shrimp wastes represent on a global scale. Chitosan has strong antimicrobial activity against a variety of microorganisms, and it is non-toxic, biocompatible and biodegradable, which make it adequate for applications as a food ingredient and in medical applications. It has also certain antitumor properties revealed both in vitro and in vivo. Chito-oligosaccharides also exhibited scavenging activity on hydroxyl and superoxide radicals, this being dependent on their molecular weight. This property makes them potential additives for the inhibition of lipid oxidation in food, but can also prevent certain pathological processes associated with free radical modification of cellular compounds, such as atherosclerosis, arthritis, diabetes, inflammatory disorders, and neurological disorders such as Alzheimer’s disease. Other applications of chitin and chitosan are their use as ingredients of toothpaste, shampoo, hand and body cream, for cell immobilization, and as materials for the production of contact lenses. Chitosan finds extensive applications in food industries, pharmaceutical applications, chemical industries, dental and surgical uses as a hemostatic agent, wound healing, biodegradable films as a substitute for artificial skins for removing toxic heavy metals, agriculture, photography, and textiles.

Conclusion

Commercial processing of fish and shellfish for trade generates significant portions of the raw material as waste, which consists of heads, filleting frames, scales, viscera, gills, dark flesh, bone, and skin. An effective waste management strategy is generally comprised of three parts including waste minimization, waste characterization and waste utilization. Best Management Practices (BMP) should be stipulated for the handling of waste by plants, to focus mainly on standardization of water consumption, reduction of contact of solid waste with water, early separation and removal of solid waste, installation of efficient machinery to increase product yield, etc. The solid and liquid waste generated should undergo treatment to minimize the risk of environmental hazards. Low cost ETP technologies should be introduced to minimize the tendency towards an under-operation of ETP by processing units. Solid waste featuring a comparable nutritional quality to fresh raw material could be utilized in the production of a range of value added by-products. There is scope for the marine industry to bioprocess seafood discards and also by-catch to extract compounds that are of practical use. Many such compounds can possess interesting bioactivities such as antihypertensive, antioxidant, antimicrobial, anti-coagulant, anti-diabetic, anticancer, immune-stimulatory, calcium-binding, and other properties. It may not only lead to the control of solid waste generated from fish industries but also helps in improving fish industry economy. Hence more research and public awareness are required to explore the possibility and potential of fish processing waste closer to the production of value-added commodities for the betterment of human society. The refinement of existing technologies with inputs from advances in biotechnology can further help with the isolation of seafood components that are safe and can retain their potential bioactivities for diverse applications.

References

1. Ioannis S. Arvanitoyannis & Aikaterini Kassaveti (2008). Fish industry waste: treatments, environmental impacts, current and potential uses. International Journal of Food Science and Technology, 43: 4, pp 726-745. https://doi.org/10.1111/j.1365-2621.2006.01513.x .
2. Kim, Y.S., Park, J.W. & Choi, Y.J. (2003). New approaches for the effective recovery of fish proteins and their physico-chemical characteristics. Fisheries Science, 69, pp 1231–1239.
3. Kristinsson, H.G. & Rasco, B.A. (2000). Fish protein hydrolysates: production, biochemical, and functional properties. Critical Reviewsin Food Science and Nutrition,40, pp 43–81.
4. Zynudeen A.A., Bindu J., George Ninan., Mohan C. O., & Venkiteswarlu Ronda (2014). Recent advances in the development of nutraceuticals, health foods and fish feed from fish and shell fish processing discards (ICAR-CIFT Winter School Manual).