CHAPTER 3
Nature and Composition of Fish Processing Industrial Waste and Handling Protocols

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Introduction

The world marine capture fisheries contribute more than 50% of the total world fish production. About 70% of fish is processed before final sale, resulting in 20-80% of fish waste depending on the level of processing and type of fish. Annual discard from world fisheries including by products is approximately 20 million tonnes (25%) per year (FAO). In India, the industrial fish processing generate 3, 02,750 tonnes of waste. Among the maritime states, maximum waste generation was observed in Gujarat (30.51%) followed by Maharashtra (23%) and Kerala (17.5%) (Zynudheen, 2010). The fish processing industry in Veraval, Gujarat is major exporter of seafood and marine products. Gujarat exports 80% of its fish products to both EU and non-EU countries. In the year 2017-2018, exports from Gujarat amounted to 3 lakh metric tonnes of seafood. Since last four year Gujarat stands first in the Indian marine fish production.

The waste generation begins with the practice of discard at sea of unintentional catches. Subsequently, during processing operations, only the muscle parts are consumed and the rest is discarded. Global fish waste generation is estimated to be in excess of 100mMT and in Indian scenario it is less than 4mMT. Processing of bulk of fish, shrimp and other aquatic organisms produces a corresponding large amount of by-products and wastes (Table 1). The waste generated in the factory is seldom attended and creates environmental pollution problems like, off smell, proliferation of insets and pests and other microbes. Moreover, these wastes are also dumped in to the environment without further treatment cause environmental pollution and also it results in loss of huge quantity of nutrients. The fish waste can be of solid waste and liquid waste. The liquid waste more of seafood processing effluents. The solid waste includes skin, bone, head, frames etc. depends on the processing of seafood. Reports suggest that fish and shrimp processing effluents are very high in biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), fat-oil-grease (FOG), pathogenic and other microflora, organic matters and nutrients, etc. Fish and shrimp processing effluents are, therefore, highly likely to produce adverse effects on the receiving coastal and marine environments. Although substantial reduction of the waste loads is possible by applying available simple techniques, this is not practiced in most part of the world due to lack of proper managerial and regulatory approach.

The waste water from seafood processing plants contains large amounts of organic matter, small particles of flesh, breading, soluble proteins, and carbohydrates. Characterization of the shrimp and fish processing waste is particularly important not only for the protection of the ecosystem but also for the sustainability of the fishery itself.

Table 1: The waste generation from seafood processing (Zynudeen et al., 2010)

Products	Waste Generated (%; w/w)
Shrimp products	50
Fish fillets	65
Fish steaks	30
Whole and gutted fish	10
Surimi	70
Cuttle fish rings	50
Cuttle fish whole	30
Cuttle fish fillets	50
Squids whole cleaned	20
Squid tubes	50
Squid rings	55

Waste composition of fin fish processing

The processing of fish involves grading, slime removal, de-heading, washing, scaling, gutting, cutting of fins, meat bone separation and steaks and fillets. These by-product wastes (mainly head, bones, skin, viscera and sometimes whole fish) contain good amount of protein rich material that are normally processed into low market-value products, such as animal feed, fish meal and fertilizer. Fish waste proved to be a great source of protein (58 % dry matter) and fat (19 %) and minerals (Renuka et al., 2016 & 2017). Several bio-techniques have been developed to utilize these protein rich fish processing by-product wastes for recovering the essential nutrients and bioactive compounds that would help the improvement of human health and waste utilization.

Protein

Fish frames contain significant amounts of muscle proteins. These muscle proteins are highly nutritious and easily digestible. Therefore, proteins from this part of the fish waste can be extracted by enzymatic hydrolysis rather than being discarded as waste. Proteins derived from fish are nutritionally superior when compared to those of plant sources. They have a better balance of the dietary essential amino acids compared to all other animal protein sources. However, fish muscle proteins are more heat sensitive than mammalian muscle proteins.

Fish protein hydrolysates (FPH) are the mixture of amino acids and peptides obtained by digesting proteins from fish meat or fish processing waste with proteases. The promising bio-technique which is currently employed to recover the nutritional and physiological important peptides is the biologically active fish protein hydrolysates (FPH). Bioactive peptides in FPH have been found to possess many physiological functions, including antioxidant, antihypertensive, anticoagulant, antimicrobial, anticancer, anti-proliferative, anti-obesity and anti-diabetic activities.

Gelatin is derived from the fibrous protein collagen, which is the principal constituent of animal skin, bone, and connective tissue. Gelatin is produced via the partial hydrolysis of native collagen. Among the processing discards, skin and bone occupies a major proportion (30% of the total mass) with high amount of collagen and is generally dumped as discards or utilized for fish meal production (Wasswa, Tang, & Gu, 2007). Since fish skin contains a high amount of collagen and gelatin, conversion of fish skin into gelatin paves a path to a cleaner environment. Gelatin is used in several applications as an emulsifier, stabilizer, wetting agent, fining agent, biodegradable packaging films, microencapsulating agent due to their functional properties such as viscosity, gel strength, gelling and melting points. Apart from food industries, it also used in photographic, pharmaceutical and cosmetic field. Nowadays, aquatic animal sources are gained interest for gelatin production because of several hindrances such as religious constraint, disease and vector transmitting medium of terrestrial animal source.

Lipids

Fish processing by products contain fish oil. The amount generally depends upon the fat content of the specific fish species. Generally, fish contains 2-30% fat. Almost 50% of the body weight generated as waste during the fish processing would be a great potential source for good quality fish oil which can be used for human consumption or production of biodiesel. The fish oil consists of two main fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These two fatty acids are polyunsaturated fatty acids and are classified as omega-3 fatty acids. The processing discard of head, intestine and liver and sometime small fatty fishes reflects the prominent presents of omega 3 fatty acids. (Renuka et al., 2017 & Khoddami et al., 2009).

Minerals

Fish bones are normally separated after removal of muscle proteins from the frames. The fish bones account for 30 % of the collagen and are considered an additional source of collagen along with fish skin. Fish bones contain 60-70 % minerals including calcium, phosphorous and hydroxyapatite. Generally, calcium is deficient in most of the regular diets and to improve calcium intake, consumption of small whole fish can be nutritionally valuable. The fish bones obtained from the fish processing waste can be used extract hydroxyapatite. It is mainly used as a bone graft material in medical and dental applications.

Enzymes

The internal organs of the fish are a rich source of enzymes, many of which exhibit high catalytic activities at relatively low concentrations. The enzymes which are available in fish include: pepsin, trysin, chymotrypsin and collagenase. These enzymes are commercially extracted from the fish viscera in a large scale. They possess better catalytic properties, good efficiency at lower temperatures, lower sensitivity to substrate concentrations and greater stability in a wide range of pH.

Fish silage

Fish silage is a liquid product resulting from the liquefaction of a whole fish or a part (Tatterson & Windsor, 1974). Liquefaction is an autolytic process carried out by enzymes already present in the fish and accelerated by an acid that induces the proper conditions for the enzymes to breakdown the tissues and limits the growth of spoilage bacteria (Gildberg, 1993). Ensilage of fish waste, although practised in some countries several years ago, is not widely used nowadays because of the high water content, which may render transportation expensive. Moreover, fish waste silage is characterised by a disagreeable odour and this may considerably limit its use in high proportion of feed formulations.

Fish meal

Fishmeal is a dry powder prepared from whole fish or from fish filleting wastes which are unacceptable for human consumption. The raw materials are transported to the processing factories either fresh or preserved in formaldehyde or sodium nitrate (Hussein et al.,1991). The production of fish meal is carried out in six steps: heating, pressing, separation, evaporation, drying and grinding. When the fish is heated the protein present in it coagulates and ruptures the fat deposits. This liberates oil and water. The fish is then pressed which removes large amounts of liquid from the raw material. The liquid is collected to separate oil from water. The water which is also known as stick water is evaporated to a thick syrup containing 30 to 40% solids. Then it is subjected to drying using press cake method to obtain a stable meal. This meal is grinded to the desired particle size. Fishmeal obtained from wild-harvested whole fish and shellfish currently makes up the major aquatic protein source available for animal feed.

Waste composition of shellfish processing

Annually, Indian shrimp industries produces more than 1 lakh tons of shrimp by products. Processing of shrimps generates large quantities of solid wastes contains head and body shell accounts approximately to 40-50% of whole shrimp weight. With approximately 75% of the total weight of crustaceans (shrimp, crabs, prawns, lobster, and krill) ending up as by-products (Hamed et al., 2016). The tropical shrimp’s head generally constitutes 34-45% and body shell constitutes 10-15%. These wastes contain protein (35-40%), chitin (10-15%) minerals (10–15%) and carotenoids (Sachindra et al, 2008).

Carbohydrate

Chitin is the second most important natural polymer in the world. The main sources exploited are two marine crustaceans, shrimp and crabs. Chitin and its derivatives are the major by product from crustacean processing. Synowiecki & Al-Khateeb, 2003 found that lobsters shell contains 60-75% chitin on dry mass of exoskeleton. The chitin content The chitin content of shrimp (14-42%) and krill (39-49%) waste is higher than in the case of crab processing waste (13-26%)on a dry basis(Ashford et al.,1977; Naczk et al.,1981). The deacetylated form of chitin is known as chitosan. Chitosan, which is soluble in acidic aqueous media, is used in many applications (food, cosmetics, biomedical and pharmaceutical applications).

Shrimp waste is one of the most important natural sources of carotenoids (Shahidiand Brown, 1998). Shrimp waste, such as head and body carapace, was used for carotenoids extraction using organic solvents. The major by-products from cephalopod are bone, ink, beak and skin. In general, squid and cuttle fish contained 3–20 % of chitin (Patil and Satam, 2002). Sometimes, higher quantities of chitin were observed, for example, the chitin content was about 40 % of the original weight of the dried pens. Cephalopods are rich in collagen, at different concentrations, from 3 to 11 % in the mantle of Loligo squid (Sikorski and Kolodziejska, 1986), 18.33 % in the mantle of jumbo squid (Torres-Arreola et al., 2008). Also, skins are rich in collagen: About 70–80 % of the squid skin dry matter is collagen. Cuttlefish bone from cuttlefish is rich in calcium. Shells are found to be the richest sources of calcium carbonate and have been utilized for various purposes after following appropriate treatments. Cephalopod by-products, because of their high content of proteins, could be considered as a good candidate to be an organic fertilizer.

Handling protocols of fish waste

Fish wastes are highly prone to spoil due to its composition. As fish waste are heterogeneous in nature there are several EU and national regulations and recommendations particularly for those intended for man and animal nutrition. EC Disposal, processing and placing on the market of animal by-products regulations (SI 257, 1994) regulates the use, sale and disposal of high and low risk animal by-products which provides limited options for their use. EC regulation No.1774/2002 of the EU laying down health rules concerning animal by-products not intended for human consumption.

Conclusion

In conclusion, fish waste represents a diverse array of bio-molecules with numerous potential valorizations. Abundant studies have been made concerning the opportunity to develop new products by processing seafood waste. Nevertheless, the major problem to industrialize these developments is the freshness of the fish waste. Fish waste must be better considered as raw materials than wastes, onboard as well as at the processing plants, with the aim of maintaining freshness of by-products and minimizing the rate of enzymatic degradation and microbial spoilage, which are higher in by-products such as viscera. For use in high-value applications, proper icing and preservation and storage of fish waste are essential.

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