Review Article

FUTURE PROSPECTS AND TRENDS FOR EFFECTIVE UTILIZATION OF FISH PROCESSING WASTES IN INDIA

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ABSTRACT

In India, the problem of fish waste has concerned considerable attention to the food producers, processors, retailers, and consumers as the waste from fish generated in a huge amount from the fish processing industries, retail markets and also from the by-catch at the fishing harbor. The continuous increase in global fish resources results in 25% of wastage among total fish catch annually. During 2006-07, an estimate of 3, 02,750 tones of waste was generated from fish processing industries of India alone. Non-utilization or underutilization of these waste products not only cause negative externalities to society but also lead to environmental pollution and ecological onus. To secure from pollution and to reduce waste, it is now become important to have a comprehensive understanding about the recycle and/or conversion of these fish wastes into useful products of higher nutritive value and betterment of human society. Thus, the effective utilization of fish processing waste materials from the fish processing sectors has been reviewed here.

INTRODUCTION

Aquaculture is one of the fastest growing food sectors providing an ultimate livelihood option to millions of peoples across the world. In the last three decades, capture fisheries production increased from 69 million to 93 million tons; during the same time, world aquaculture production inflated from 5 million to 63 million tons. Globally, fish currently represents about 16.6 percent of animal protein supply and 6.5 percent of all protein for human consumption (FAO, 2012). About 30% of the total fish weight remains as waste in the form of skins and bones during the preparation of fish fillets. This waste is an excellent raw material for the preparation of high value products including protein foods Fisheries generate large amount of solid wastes such as whole fish waste, fish head, viscera, tails, skin, bones, blood, liver, gonads, guts and some muscle tissues and also liquid wastes consisting of wastewater used during fish processing. Fish processing generates a huge amount of solid wastes that can be as high as 50-80% of the original raw material. Skin and bone are sources of the processing waste considered as of high collagen content. An important waste reduction strategy for the industry is the recovery of marketable by-products from fish wastes. Every year, an enormous amount of these processing wastes are discarded from seafood processing plants and fish markets. Because of the specificity of certain raw material and its processing in relation to a specific product, surplus and waste food processing co-products are not readily used by the parent processors. The maximum waste was generated from processing of shrimps followed by finishes and cephalopods. On the context of environmental pollution, waste generation from fish processing is of great concern today. This waste is a superlative raw material for the preparation of high value-added products including proteinaceous foods. These are also a valuable source of raw material for recovery of bioactive compounds. Additionally, inappropriate disposal is a major cause of environmental pollution. The utilization of fish waste helps to eliminate detrimental environmental aspects and revamp quality in fish processing. However, recent advances in industrial biotechnological processes have paved way for economical and highly serviceable utilization of these wastes for mankind. The recovery of chemical components from seafood waste materials & fish processing units, which can be used in other segments of the food industry, is a promising area of research and development for the utilization of fish waste by-products. There is an estimate of waste generated from fish processing industry are given in Table 1. These wastes cause a serious problem of environmental pollution and make the environmental atmosphere unhygienic prone to various kinds of diseases. So there is a problem remains what to do with these wastes. One best alternative way is to convert these wastes to value-added bioactive and different products for the use of mankind and other animals. The valuable products that could be developed from all these fish processing waste materials are described below in brief.

Table 1. Waste generation in industrial fish processing in India

Products	Waste generated (%)
Shrimp products	50
Fish fillets	70
Fish sticks	30
Whole and gutted fish	10
Cuttlefish rings	50
Cuttlefish whole	30
Cuttlefish fillets	50
Squid whole cleaned	20
Squid tubes	50
Squid rings	55

*Anon, 2005

As a material for enzyme production

The major fish wastes usually found in the market are fish viscera, head, tail, scales etc. Fish viscera is consists of different types of food materials, have the property of enzymatic hydrolysis of different types of proteolytic enzymes that secreted to the gut. Enzymes and bioactive peptides can be attained from fish waste and used for fish silage, fish feed or fish sauce production. An alternative way to convert the fish processing wastes into more marketable products is to isolate and purify proteolytic enzymes which are abundant in fish viscera. Proteases or the proteolytic enzymes that are found in the gut could be helpful in fish protein hydrolysate production. Proteolytic enzymes such as alkaline, a-chymotrypsin, neutralise, papain, pepsin, trypsin, pancreatin, flavourzyme, bromelain, pronase E, protamex, orientase, thermolysin, validase, protease A amano, protease N amano and cryotin F that derived from plant, animal, and microbial sources have been successfully tested for the production of antioxidative peptides from fish protein sources. Protease is a group of enzyme that makes proteolysis known as hydrolysis of the peptide bonds, which link amino acids together in the polypeptide chain forming the protein. Proteases represent one of the largest groups of industrial enzymes and are mainly derived from animal, plant, and microbial sources. Today, there is an increasing demand for fish proteolytic enzymes due to their wide range of applications. Proteases play an important role in industries due to their multifarious applications in leather and detergent industry, food and pharmaceutical industries and also in bioremediation processes.

As a material for fish protein hydrolysate (FPH) production

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 flavorings. 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. For example, improved capacities of oil-binding and emulsifying are required for meat products and spread texture food respectively. 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 (Gopakumar, 2002). Most hydrolysates are bitter in taste after the time of production. Therefore flavoring agents are like cocoa, and sugar should be used during the fortification in food preparation to mask the bitter taste (Thankamma *et al.*, 1979).

As a material for fish meal production

Fish meal is the most important products obtained from fish waste, by-catch, and other abundant species. 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 food 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 (Windsor and Barlow, 1981). Traditionally fishmeal production was from the sundried fish collected from various drying centres and the product was mainly used as manure, but now a day, the fish meal can be produced by two general processes like dry rendering and wet rendering. Process conditions also affect the meal quality. Superior quality fish meals have been a prominent item of export from the very beginning of the industry. BIS has brought out the specifications for fish meal as livestock feed for facilitating proper quality control (Brody, 1965).

As a material for fish silage production

Viscera of fish include the digestive tissues (stomachs, pyloric caeca, intestines, liver, pancreas, etc.) and other organs like spleen and gonads. Viscera waste was used to obtain fish silages. 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 (Raa and Gildberg, 1982). 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 of aquaculture, fish diet is determined basically by the amino acid composition of the feed and 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 (Nair *et al*., 2004).

As a material for fish oil production

Fish oils can be extracted from the whole fish, skin or liver (in the case of some species). 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. At present, the medicinal values of fish oil are very well known (Stansby, 1967).

As a material for collagen and gelatin production

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 it has 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 (Kims and Mendis, 2006). The amount of gelatin obtained from fish and other species increased consistently from 2003 to 2005 with a growth of 0.7% to 1.3% of total world production (Ninal *et al*., 2009).

Miscellaneous uses

Fish calcium

Filleting waste of bigger fishes are very good sources of calcium which can be used for the pharmaceutical purpose.

Pearl essence

Pearl essence is the suspension of crystalline guanine in a solvent. It is the iridescent substance located in the epidermal layer of the scales of pelagic fishes. This is used for coating the objects to give them a lustrous effect.

Fish glue

Fish glue is made from fish skins (better quality glue) and fish heads (lesser quality glues). A sequential cooking of fish skin with acid and alkali yields fish glue.

Fish maws and isinglass

Sturgeon fish's air bladder or swim bladder is usually referred as isinglass. In India, air bladder of eels and catfishes are used for the production of isinglass. The air bladders are separated from fish and temporarily preserved in salt during the time of transport. On reaching the shore, they are split open, thoroughly washed and outer membrane are removed by scraping and then air dried (Mathew, 2003). Then cleaned, desalted, air dried, and hardened swim bladders are called fish maws. Isinglass is used as clarifying agents for beverages, wines, beer, and vinegar by enmeshing the suspended impurities in the fibrous structure of swollen isinglass.

Bioactive compounds

New biologically active compounds have been isolated from fishery discards. One example is the discovery of the antifungal and antibacterial properties of the epidermis, epidermal mucus of different fish species, liver, intestine, stomach, and gills of some fish species and the blood and shell of some crustaceans. Fish mucous is known to have significant biological functions, acting as an immunological barrier. A variety of biologically active compounds, proteinases, peptides, or polypeptides with high molecular weight are responsible for these functions.

Antifreeze proteins

Antifreeze proteins (AFPs), which are found in diverse species of marine fishes, are characterized by their ability to prevent ice formation by cooling below the freezing point. This is a protection method of polar fishes against freezing. It is found that snail fish skin tissue shows antifreeze activity that can be purified by chromatography techniques. Some work has also been carried out on the extraction of AFPs from winter flounder (*Pseudopleuronectes americanus*), cunner (*Tautogolabrus adspersus*), sea raven (*Hemitripterus americanus*), and short horn sculpin (*Myoxocephalus scorpius*). The main application of AFPs is as cryoprotectants since they can prevent freezing damage by their capacity to lower freezing point and inhibit ice recrystallization. Some studies revealed that the addition of AFP to meat or injection into animal reduces the damage caused by frozen storage of meat.

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 *Penaeus indicus*, 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 properties 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 (Rajalakshmi and Mathew, 2007). The laboratory method worked out for the preparation of chitin and chitosan are also developed by CIFT, Kochi (Madhavan and Nair, 1974). An additional pioneering use for carboxymethyl chitin is in wound dressing, due to its property of hydrophobicity (Sini *et al*., 2005).

Bio-oil

Fish oil, a fish powder by-product, was pre-treated by filtration, placed in a reactor with two catalysts (iron oxide and calcium phosphate monobasic) and mixed with ozone bubbling (about 8000 ppm) for one hour room temperature which is called primary ozone treatment. Some scientists evaluated the ozone treated fish waste oil as a transportation diesel fuel. Then the sample was filtered again and treated with ozone at the same conditions for 30 min, but without the presence of catalysts called as secondary ozone treatment. The oil manufactured from fish waste was tested for its density, flash point, pour point, heating value, distillation test, and sulfur content. The yield of the produced fuel was 95–96%, after filtration, primary and secondary treatments. The method of production of bio-diesel from fish source is also reported by Arvanitoyannis and Kassaveti (2007). The obtained oil was found to have suitable properties for use in diesel engines, such as almost identical higher heating value compared with commercial diesel fuel, no production of sulfur oxides, lowered or any soot, polyaromatic and carbon dioxide emissions. These properties suggested that the obtained oil had better properties than methyl-esterified vegetable oil waste and was suitable for diesel engines, especially at low temperature.

CONCLUSION

Instead of dumping, the utilization of unwanted fish wastes as a low-cost feedstock along with traditional fishery by-products a better option for production of value-added products and also as health supplement can be considered. 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.

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