20. High value byproducts from fish processing discards

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Aquatic food consumption at global scale increased at an average annual rate of 3.1% from 1961 to 2018 with the per capita annual consumption value from 9.0 kg to 20.5 kg. There are various factors contributes for this increment. One of the factors is awareness among the consumers about the health benefits of consuming fish and its richness in terms of nutritional value. Fish is considered as nature's superfood as it is not only the source of high-quality proteins (well balanced amino acid composition and high digestibility), it is also a rich source of therapeutic fatty acids (Poly Unsaturated Fatty acids) and unique source of essential nutrients (essential amino-acids, essential fatty acids, minerals and vitamins). Another important factor is the growth in global fish production and indirectly the availability. It is projected that by 2030, around 62% of global fish consumption will be met by farm raised fishes, which was only 49% in the year 2012. The contribution by farm raised fish to consumption increases while contribution by wild caught category decreases (51% in 2012 and projected to be 38% by 2030).

The raise in fish consumption drives the growth in fish processing and associated sector. On the other hand, fish is a highly perishable commodity due to low connective tissue content, low glycogen reservoir, near neutral postmortem pH, nature of post-mortem autolytic process, nutrients density and high moisture content. Processing of fish is highly essential in order to preserve its nutritional value and wholesomeness and to make it available across the continents. The processing activities lead to generation of various parts of the fish as by-products/processing discards. Discards generated from fish and shellfish includes scale, skin, bone, visceral mass, belly flaps, fins, exoskeleton and head waste from crustacean, shuck-water from clams and oysters, meat washed water from surimi industry, ink-gland, beak and tentacles from cephalopods, reproductive organs, etc. The quantity of discards generated during fish processing may vary from 30-75% of raw material weight depending on the type of processing, type product and type of raw material. Some of the products and quantity of waste generation is presented in Table 1. Globally around 32 million tones of fishery raw material is estimated to be wasted in the form of processing discards.

When not addressed properly, fish processing discards turn to be a huge issue from the perceptions of resource underutilization, resource wastage, economical loss and environmental destruction. On the other side, when it is properly used, fish processing discards can be a potential solution to achieve the sustainability in fisheries, to improved food and nutritional security, to achieve the global economical growth, for being healthy people and to preserve the healthy environment and this blue planet. Globally, fish waste management is a serious issue and fish waste utilization has become an objective of global governing policies laid down by various international organizations.

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Table 1. Waste generation during industrial processing

Products	Waste Generation (%; 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

Biochemical nature of fish processing discards

In terms of biochemical composition, fish discards are very close to the edible fish meat portion. The quanity of constituents are almost same, but the quality differs as the nature and type of molecules and their proportions in the discards are different. For an instance, scale, skin bone and fins are rich source of the connective tissue proteins particularly the collagen fraction is high. Similarly, the meat in head portion, cutting residues (cutting dusts), filleting frame waste meat are rich in structural proteins including myosin, actin, troponin, tropomyosin etc.

Table 2. General composition of fish discards

Nutrients	Composition*
Crude protein (%)	57.9 ± 5.3
Fat (%)	19.1 ± 6.1
Crude fiber (%)	1.2 ± 1.2
Ash (%)	21.8 ± 3.5
Calcium (%)	5.8 ± 1.3
Phosphorous (%)	2.0 ± 0.6
Potassium (%)	0.7 ± 0.1
Sodium (%)	0.6 ± 0.1
Magnesium (%)	0.2 ± 0.1
Iron (ppm)	100.0 ± 42.0
Zinc (ppm)	62.0 ± 12.0
Manganese (ppm)	6.0 ± 7.0
Copper (ppm)	1.0 ± 1.0

The wash water from surimi industry and shuck water from depuration of molluscs are rich source of water-soluble proteins (sarcoplasmic proteins) including albumins, globulins, and enzymes. Except bony part of fish discards, other waste parts are generally rich in protein accounts to 45-60% of raw material on dry weight basis. Next to protein the major constituent is lipid. Fish eyes, belly flaps, fish head, visceral mass are all rich source of lipids. On dry basis, fish discards in general contains around 4-20%. Fish bone and fish scale serve as rich source of fish calcium and phosphate. The general composition of fish discard is presented in Table 2.

With the continuous efforts from researchers across the globe, it has been possible to produce various high value products from fish processing discards. The following classification of possible products from fish discards may be considered for all the academic purpose.

Edible products

- Fish bone broth/soup
- Fish head stock
- Products from recovered meat from waste

Industrial products

- Fish oil
- Fish meal

Feed /Fertilizer

- Fish silage
- Fish manure/compost
- Fish protein hydrolysate
- Foliar spray

Specialty products

- Ambergris
- Fish Skin Leather
- Flavor Extract
- Caviar substitutes

Bio-functional/ health products/High value products

- Chitosan derivatives
- Collagen derivatives
- Fish protein hydrolysate
- Glucosamine
- Chondroitin sulphate
- Squalene
- Sulphated polysaccharides
- Hyaluronic acid
- Fish bone calcium
- Hydroxyapatite
- Pigments
- Enzymes

High value products from fish processing discards of commercial interest

In spite of enormous number of research reports, only very few products have been turned into commercial production. Fish collagen peptide, chitosan, PUFA, Astaxanthin, Squalene, Fish protein hydrolysates and bioactive peptides, fish/shrimp flavor extracts and fishbone calcium supplements are some of the examples for high value fish products produced from fish waste. High value products from fish processing discards of commercial interest with their market value and potential is presented in Table 3. The value addition to these discards may range from 2-20 fold of raw material cost. In some occasion, the fishery waste is considered as zero cost raw materials.

Table 3. High value products from fish processing discards of commercial interest with their market value and potential.

Raw material	Product	Value/Unit (USD)	Market growth projection
Skin/Scale/Bone	Fish collagen/Fish gelatin/Collagen peptide	10-50/kg	USD778 million – 2021 USD 1,137 million by 2026, CAGR of 7.9%
Crustacean shell waste	Chitosan	9-25/kg	USD 476.6 million-2016 SD 1,088.0million- 2022, CAGR-14.7%
Fish body/Liver	Fish oil/PUFA	10-100/kg	USD 1788 million-2021 USD 2623million- 2028, CAGR-5.6%
Shark liver	Squalene	20-260/kg	USD 129 million-2020 USD 184 million -2025, CAGR - 7.3%.
Shrimp/shellfish waste	Astaxanthin	60-300/kg	USD 1.33 billion-2020 CAGR-15.1%
Fish discards	Fish bioactive peptides/protein hydrolysate	5-50/kg	USD254 million USD 361.5 million -2027 CAGR-5.1% Market volume -50,278.3 tons
Shrimp waste	Shrimp flavor	5-10/kg	---
Fish viscera	Fish enzymes	---	---
Fish bone	Fish bone calcium	5-8/kg	---

There are practices in some parts of countries where the industry pays to the waste collector for taking the fish discards.

Proteins from secondary raw material and the possible industrial products

Fish processing discards are rich in fish muscle proteins (Myosin, actin troponin, tropomyosin etc.), connective tissue proteins (Collagen and its derivative gelatin), fish enzymes, hemoproteins and carotenoproteins. The relevant industrial products which exploit the above-mentioned proteins are fish protein concentrate, surimi from frame meat, fish meal, shrimp head meal, squid meal, dried fish scale and dried fish skin.

Table 5. The protein components from secondary raw material and the relevant possible industrial products

Proteins from secondary raw material	Protein rich industrial products from secondary raw material
• Fish muscle proteins (Myosin, actin troponin, tropomyosin) • Collagen • Gelatin • Fish enzymes • Hemoproteins • Carotenoproteins	• Fish protein concentrate/fish protein powder • Surimi • Fish meal • Shrimp head meal • Clam meal • Squid meal • Dried fish scale • Dried fish skin

Fish protein concentrate

Fish protein powder (FPP) is a dried fish product, meant for human consumption, in which the protein is more concentrated than in the original fish flesh. Different methods for the separation of meat from fish are employed, such as washing meat with water for two to 3 cycles and concentrating, solubilization of muscle by pH adjustment and iso-electric precipitation, solvent extraction to method to remove the fat, cooking and drying, and a combination of various methods. The raw material such as fish filleting frames, head waste, tuna red meat and belly flaps can be used to produce fish protein concentrate

Earlier studies conducted on rat have shown that fish proteins have greater cholesterol lowering ability (Ammu et al., 1989) and can protect the animal against lipid peroxidation. Fish protein reduces serum cholesterol, triglycerides and free fatty acids and increases the proportion of HDL cholesterol. In general, protein supplements claims to help weight loss and muscle building. Fish protein supplement have shown beneficial effects on blood levels of glucose and LDL-cholesterol as well as glucose tolerance and nutritional composition of body in overweight adults (Vikoren et al., 2013). In another study, dietary scallop protein completely prevented high-fat, high-sucrose-induced obesity whilst maintaining content of lean body mass and improving the lipid profile of plasma in male C57BL/6J mice (Tastesan et al., 2014).

Fish Collagen

Collagen is a structural protein found mainly in the skin and bones of all animals. Collagen is the most abundant protein originating from the animal source, comprising approximately 30% of total animal protein. It is composed of three α-chains which are intertwined to form a triple-helix. It is present in the connective tissue matrix that makes the framework of skin, bones and joints, cornea, blood ducts, and the placenta. There are many types of collagen, but 90% of our body's collagen protein is Type-I collagen. It is found to be rich in amino acids such as glycine, valine, alanine, proline and hydroxyproline (Burghagen, 1999). Glycine constitutes one third of the total amino acid content of collagen followed by hydroxyproline and proline, which account for another one-third. Owing to this structural uniqueness of collagen molecule, there is increasing interest for the direct consumption of collagen in the form of their easily digestible derivatives. Worldwide, this interest has been taken-up by the nutraceutical industry, especially in developing countries.

Currently, collagen is used in many pharmaceutical and cosmetic products, due to its structural role and better compatibility with human body. It is commonly used in the cosmetic industry for the production of skin lotions as it forms a superior protective film to soothen and hydrate the skin. Such potential of collagen has tremendous bearing on anti-aging treatment. Apart from that, collagen has a wide range of applications in the field of cosmetic and burn surgery, especially as dermal fillers in the reconstruction of skin and bone. Collagen gels have potential clinical importance in the preparation of 'artificial skin' used in treating major wounds. Injectable collagen hydrogels have been successfully used for soft-tissue augmentation, drug delivery carriers and hard-tissue augmentation. Microfibrous collagen sheets are used as promising drug carriers for the treatment of cancer. It is also an essential component in diverse orthopedic and dental treatments. Further, collagen is recently projected as a joint mobility supplement.

Fish Gelatin

Gelatin is a soluble polypeptide obtained by denaturing the insoluble collagen. Procedures to derive gelatin involve the breakdown of cross-linkages existing between the polypeptide chains of collagen along with some amount of breakage of intra-polypeptide chain bonds. Tissues that contain collagen are subjected to mild degradative processes, i.e., treatment using alkali or acid followed or accompanied by heating in the presence of water, the systematic fibrous structure of collagen is broken down irreversibly and gelatin is obtained. It is the only protein-based food material that gels and melts reversibly below the human body temperature (37°C). Gelatin possesses unique and outstanding functional properties and can be obtained in reasonable cost, make it one of the most widely used food and pharmaceutical ingredient.

Fish skins and bones can be utilized to produce gelatin, thus contributing to solve the problems of waste disposal with the advantage of value addition. The main drawback of the fish gelatins are the gels based on them tend to be less stable and have inferior rheological properties compared to mammalian gelatins. It may be noted that fish gelatin has its own unique properties like better release of a product's aroma and flavor with less inherent off-flavor and off-odor than a commercial pork gelatin, which offer new opportunities to product developers.

Fish enzymes

Fish visceral waste can serve as a source of large amount of enzymes which have potential applications in different sector starting from laundry application to pharmaceutical applications (Simpson and Haard, 1987). The nature of fish visceral enzymes is different from the enzymes found in the digestive system of terrestrial animals. Hence, they can be exploited for certain distinct applications. Fish pepsins can act even at low temperature and higher pH optimum than the pepsins from terrestrial source. Moreover, fish pepsins do not undergo autolysis at low pH (Raa, 1990). The differences in the properties of pepsins from fish and other sources could be attributed to the difference in the sequence and composition of aminoacids (Gildberg and 0verbj, 1990). Fish enzymes can be used as processing aids in the following applications

- Protein hydrolysates production
- In production of caviar from a variety of fish species
- for removal of squid skin
- for cleaning of scallop
- for descaling of fish
- coagulation of milk
- Cheese production

Hemoproteins

Hemoproteins are complex proteins, composed of a protein molecule and a non-protein compound (prosthetic group). Hemoglobin and myoglobin belongs to the category of hemoproteins involves in transport of oxygen in the blood and tissues of animals, respectively. The heme portion can be recovered from blood as well as muscles discards. The recovered material may be used iron supplement or as a chemical substrate for production of the cooked cured-meat pigment. During the production of hydrolyzates from meat, hemin could be recovered as by-product.

Carotenoproteins

Carotenoproteins and carotenoids are other classes of compounds found in the flesh and skin of fishes and in the exoskeleton of shellfish. They are not synthesized in their body. They are acquired through their food chain (Haard, 1992). Similar to hemoproteins, Carotenoids are also composed of a protein moiety and a non-protein prosthetic group. Isolation of carotenoproteins and carotenoids from shellfish processing discards has been reported (Long and Haard, 1988). Inclusion of caratenoids pigments in feed formulations of some of the aquacultured fishes and ornamental fishes shows the importance of these compounds in industrial applications (Shahidi et al., 1993).

Fish protein hydrolysates (Bioactive peptides)

Apart from being highly nutritious, fish muscle proteins can be made use for preparing fish protein hydrolysates which comprises of bioactive peptides with valuable nutraceutical and pharmaceutical potentials. 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 size of these peptides may range from 2 to 20 amino acid residues with the molecular masses of <6000 Da and are highly bioactive. The food derived peptides can be used as functional food ingredients or as nutraceuticals to benefit the human health and prevent disease. In this context, large pharmaceutical companies are more interested to invest in bioactive peptide research to open therapeutic prospects.

Chitin

Chitin is a nitrogenous polysaccharide (poly N-acetyl Amino D- glucose) found in the outer skeleton of insects, exoskeleton of crabs and shrimps and internal structure of lobsters and other invertebrates. It is the most abundant organic compound next to cellulose in the earth. Chitin represents 14-27% and 13-15% of the dry weight of shrimp and crab processing waste respectively (Ashford et al., 1977). Chitin is present as chitin protein complex along with minerals mainly calcium carbonate. So the process of chitin production consists of deproteinisation with dilute alkali and demineralization with dilute acids. Chitin on deacetylation gives chitosan and on hydrolysis with concentrated HCl gives glucosamine hydrochloride. CIFT has developed technology for production of chitin, chitosan and glucosamine hydrochloride from prawn shell waste.

Carboxymethyl chitin

Carboxy methyl chitin is another value shot derivative of chitin. The conversion of chitin into carboxy methyl chitin came in to practice by carboxymethylation. It has successfully proved its use in the field of cosmetics as moisturizer, skin smoothener and a cleaner for face skin conditioning it is used for the preparation of food products also.

Chitosan

Chitosan is prepared by deacetylation of chitin. Chitosan is almost colourless, light in weight and soluble in dilute organic acids. Its uses are hindered due to its insoluble nature in water, alkali and organic solvents. It gives viscous solution when dissolved in dilute organic acids such as formic acid, acetic acid, citric acid etc. Chitosan finds extensive applications in pharmaceutical applications, food industries, chemical industries. Chitosan is used in dental and surgical appliances as a haemostatic agent, wound healing, biodegradable films as a replacement for artificial skins for removing toxic heavy metals, wine clarification, industrial effluent treatment, agriculture, photography, cosmetic applications and textiles and as an immobilizing agent for enzyme.

Glucosamine hydrochloride

Glucosamine is chemically glucose in which a hydroxyl group on the second carbon atom is substituted with an amino group. It crystalizes as glucosamine hydrochloride during purification under acidic conditions. It is one of the amino sugars used by biological systems for bringing modification to the functions of proteins

Glycosaminoglycans (GAGs)

Glycosaminoglycans (GAGs) are heteropolysaccharides consist of repeated unit of disachcharides and no branched chains. Out of two monosaccharides, one is always an amino sugar (N-acetylgalactosamine or N-acetylglucosamine) and the other one is an uronic acid (Ronca et al., 1998; Kogan et al., 2007). They are present in the extracellular matrix of all animal cell surfaces and their function is to regulate different proteins such as growth factors, enzymes, cytokines. They finds the applications in food, cosmetic and clinical areas. The identified potential sources of glycoconjugates include mainly the marine organisms like sponges, sea cucumbers, squids, mollusks. The matrix of collagen associated with proteoglycans, macromolecules having a core protein to which the GAGs (chondroitin sulfate, keratan sulfate, dermatan sulfate and heparan sulfate) are covalently bonded by means of a tri-saccharide linked to a serine residue and form the cartilage tissue (Seno and Meyer, 1963). Hyalurunic acid (HA) is the only non-sulfated GAGs and is not covalently bound to the protein in any tissue. Chondroitin sulphate (CS) and HA are the most valued GAGs in market because of its abundance in mammalian tissues and notable physiological functions and high activity (Imberty, 2007).

Chondroitin sulphate

Chondroitin sulphate (CS) consist of repeated disaccharide units of glucuronic acid (GlcA) and *N*-acetylgalactosamine (GalNAc) linked by β-(1→3) glycosidic bonds and sulfated in different carbon positions (CS no-sulfated is CS-O). The classification and type of CS is dependent on sulfate group placing: carbon 4 (CS-A), 6 (CS-C, more common), both 4 and 6 (CS-E), positions 6 of GalNAc and 2 of GlcA (CS-D) and 4 of GalNAc/2 of GlcA (CS-B). The function of the organism and tissue influence the composition (shark, CS-D; dogfish, CS-A and CS-D; squid and salmon, CS-A and CS-E; ray, CS-A and CS-C) and concentration (e.g., 9% in shark fin and 14% in chicken keel) of CS. Thus, CS from marine sources differs in chain length and over sulfatation (Vázquez, 2013).

Chondroitin sulfate involved in various biological processes such as the function and elasticity of the articular cartilage, hemostasis, inflammation, cell development, cell adhesion, proliferation and differentiation by being an essential element of extracellular matrix of connective tissues. Chondroitin sulfate with less than 20 kDa is orally administered in nutraceutical formulations indented to treat and prevent the osteoarthritis.

Hyalurunic acid

In marine organisms, the the eyeball of fish species is the only clear source of HA is present in the vitreous humor (VH). VH volume and HA concentration varied with the fish species, for instance, HA is obtained from eyeballs of shark and swordfish at 0.3 g/L from 18 mL of VH and 0.055 g/L from 70 mL, respectively (Imberty et al., 2007). HA is also present in the cartilage matrix as structural element and of the most researched benefits of hyaluronic acid is its ability to alleviate pain in joints. Its effectiveness in this area isn't surprising since hyaluronic acid is especially concentrated in the knees, hips, and other moving joints. It is a major component of both cartilage and the synovial fluid that bathes these joints, binding to water to create a thick, gelatinous substance that lubricates and protects the cartilage. In addition to playing a vital role in joint health, another majo benefits of hyaluronic acid is its effectiveness at maintaining healthy, youthful skin. The reason is because hyaluronic acid is an essential component of the skin. The suggested oral dose of hyaluronic acid is 100–200 mg per day.

Omega-3 fatty acids

The health benefits of seafood have mainly been attributed to the marine lipids. The beneficial effects of seafood have traditionally been ascribed to the presence of omega-3 polyunsaturated fatty acids, particularly eicosapentaenoic acid (EPA) and docosa hexaenoic acid (DHA). The amounts of fatty acids most frequently found in seafood range between 8 and 12% EPA and between 10 to 20% DHA. These fatty acids accumulate in the fish muscle via the food chain from plankton. This arises from the fact that marine phytoplankton has a high ratio of EPA and DHA, and thus these fatty acids are accumulated in the food chain. These fatty acids have pleiotropic effects and influence the *in vivo* production of inflammatory components, blood rheology, and membrane functionality. Due to their potential effects in promoting health, recommendations for daily intakes of n-3 PUFAs have been published by several international scientific authorities several organization

Squalene

One of the most interesting compounds available from fish is Squalene which is found in deep sea sharks liver oils. Squalene is most abundant in the liver oils of deep sea sharks, commonly called spiny dog fish. The liver oil of these species contains about 40 to 85% squalene by weight of oil. Squalene is a polyunsaturated hydrocarbon, better known as an Isoprenoid or Isoprene. By virtue of its double bond structure attached to six Methyl [- CH3] groups the isoprenoid has an exceptionally strong antioxidative effect in cell metabolic activities

Fish bone calcium-Calcitone

It is well documented that consumption of whole small fish is nutritionally beneficial providing with a rich source of calcium. Calcium and phosphorus comprise about 2% (20 g/kg dry weight) of the whole fish. Small fish are often eaten whole, including bones. However, in the case of large fishes like tuna, bone is a major component of processing waste. Thus, the filleting wastes of tuna and other bigger fishes are very good sources for calcium when the quantity of calcium is concerned. Calcium derived from the filleting waste can be used for pharmaceutical purposes, as it is mainly in the form of calcium phosphate with ideal calcium-phosphorus ratio. Central Institute of Fisheries Technology, Cochin has optimised the process to extract from fish bone which is mainly treated as processing discard during filleting operation of larger fishes, viz tuna, carps etc. Before packing, the calcium powder was supplemented with vitamin D which is known to enhance absorption and bioavailability of calcium in the body. *In vivo* studies conducted at CIFT in albino rats have shown that fish calcium powder supplemented with vitamin D has improved the absorption and bioavailability. The product is packed in 400 mg capsules containing 200 mg calcium per capsule.

Carotenoid pigments in Shrimp

Studies on efficient utilization of shrimp industry byproducts have been concentrated mainly on recovery of chitin and chitosan from the waste. In recent years, much attention is being paid for extracting valuable constituents from shrimp waste like natural carotenoid pigments. The most prevalent carotenoid found in shrimp is astaxanthin, 3,3'-dihydroxy-i,i-carotene-4,4'-dione representing about 65-98 % of the total carotenoids present and consisting of 3 sterioisomers (3S,3'S; 3S,3'R; 3R,3'R). Three different forms of this particular pigment are recognized in crustaceans, namely diesters, monoesters and the free form. Normally, wild caught shrimps will have more pigmentation compared to their cultured counterparts. Highest carotenoid content was reported in the head of deep-sea shrimp (*A alcocki* 180-185 µg/g) and marine shrimp (*P stylifera* 150-155 µg/g) followed by *P monodon* (120-135µg/g), *P vannamei* (120-130µg/g). High levels of carotenoids were also reported in carapace of *A alcocki* (115-120 µg/g), S *indica* (117-120.0 µg/g) and *P stylifera* (100-105µg/g). Relatively low levels of carotenoids were reported in shrimp *P indicus* and fresh water prawn *M rosenbergii* and crabs. The major carotenoids in shrimps, fresh water prawn and marine crab was reported as astaxanthin and its esters. β-Carotene and zeaxanthin were reported at low levels in these species. Most of the carotenoids in shrimps are distributed in shell (nearly 84-87%) and only 12-15% is present in flesh. The recovered carotenoids can be used as colorants in food products, used as antioxidant and as pigment source in diets for ornamental fishes, farmed salmon and trouts etc. Carotenoids from shrimp waste can be used in prevention of cancer, enhancement of immune responses and improvement of visual function. Currently major application of carotenoids include nutritional supplements, pharmaceuticals, food colorants, and animal feed additives (Mohan et al., 2014).

Technologies Available for high value products with ICAR-CIFT

- Technology for edible value-added products from fish waste
- Technology for high protein snacks using fish discards based ingredients
- Technology for fish collagen peptide
- Technology for fish collagen/gelatin
- Technology for chitin and derivatives
- Technology for Astaxanthin
- Technology for melanin
- Technology for hydroxyapatite
- Technology for bioactive fish peptides
- Technology for fish protein hydrolysates
- Technology for fish bone calcium
- Technology for Squalene
- Technology for encapsulated fish oil powder

Conclusion

Globally, the aquatic food waste (secondary raw material) has been identified as source of high value functional ingredients. On the other hand current exploitation of aquatic food waste is happening as high volume low value products for example fish silage, fish meal, squid meal, shrimp head meal etc. The major high value products such as collagen and its derivatives, chitin and its derivatives, hydroyapatite and fish calcium, shrimp pigments and caratenoproteins are having a huge market potential. The way the fish waste utilized globally needs a rattled shift in order to realize the full potential of aquatic food processing waste generated.

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