Utilization of Fish Processing Waste: A Waste to Wealth Approach

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With increasing global fish production, a large quantity of material is available for processing and thereby increasing the amount of waste generated. These byproducts or waste in the form of non-edible tissues like bones, skin/scales, swim bladders, fins, intestines, blood, roes, liver etc. are rich source of valuable components such as protein, lipid, enzymes bioactive peptides, pigments, flavours, vitamins and minerals. Therefore, it is imperative to recycle these wastes into marketable products so as to add value to this waste and minimize environmental threat of pollution. Globally, 20 million tonnes (approx., 12 % of total fish production, 171 MT) is used for non-food purposes. Out of which, 15 MT is reduced to fishmeal and fish oil and the rest 5 MT is largely utilized as material for animal feed, as bait, in pharmaceutical uses and for ornamental purposes. Though the classical approach utilizes these wastes for the production of fish meal, fish oil, pet foods silage or fertilizer, the recent advances in biotechnology and processing techniques changes the traditional approach and introduces new approach to produce high value components such as collagen and gelatin, enzymes etc. Therefore, we advocate the utilization of fish processing waste for turning it into wealth.

Introduction

Fish is a broad term that includes any aquatic organisms harvested for commercial purposes, whether caught in wild fisheries or harvested from aquaculture or fish farming. The term fish (whether of freshwater, estuarine/ brackish water or marine/ salt water) include finfish, crustaceans (cray fish, crab, prawn/shrimp, lobster) and mollusks (bivalves such as mussel, oyster, scallop and univalves like abalone, snail, conch and cephalopods such as squid cuttlefish, octopus) (Sachindra and Mahendrakar, 2015). Seafood, synonymously used for marine fish, generally refers to a group of biologically divergent edible animals (excluding mammals) consisting not only of fish (finfish), whether of freshwater, estuarine, or marine habitats, but also of shellfish (Suresh and Prabhu, 2012). It seafood includes a diverse range of aquatic animals and therefore the non-edible part generated varies greatly in composition and amount (Suresh and Prabhu, 2012). In 2015, fish accounted for about 17 percent of animal protein, and 7 percent of all proteins, consumed by the global population. Fish provided about 3.2 billion people with almost 20 percent of their average per capita intake of animal protein (SOFIA, 2018). Globally fish and fish products provide an average of 34 calories per capita per day. Fish has also significant dietary contribution in terms of high quality, easily digested proteins especially in fighting micronutrient deficiencies.

Generally the yield calculated by the fish processing industry is based on a gutted fish with head-on, that is typically 40% on an average (Marsh and Bechtel, 2012). Fish processing generates 35-40% edible meat and the remaining non-edible tissues are bones, skin/scales, swim bladders, intestines, roes, liver, blood etc. (Sachindra and Mahendrakar, 2015). The demand for RTE and other value added product that requires skinless, boneless fillets further increases the amount of waste generated. Many species are inadvertently caught while harvesting fish and crustaceans and that are not processed for human consumption also adds to the waste (Marsh and Bechtel, 2012). Processing of finfishes generates 10–50% of the total weight as non-edible parts, which includes head, gut (viscera), skin, bone, and flesh remaining on the bone. Shellfishes, especially crustaceans, generate up to 85% of raw material as non-edible parts, which include head, shell (carapace), viscera, and appendages (Suresh and Prabhu, 2012). Fish processing discards usually accounts for 3/4th of total weight of catch. Discards are generally dumped in-land or hauled into the ocean. Meal and silage has also the potential of waste utilization. Recently, the focus is on the potential utilization of tongue, cheek, stomach, liver, fish skin, chitnous material, careteniod pigments, flavourants, gut enzymes, anti-freezing proteins etc. (Shahidi, F., 1994). Filleting generates discards up to 75%. Entire offals from cod fishery may be used as a feed component, silage or fish meal. Protein value of offals is usually estimated by protein efficiency ratio (PER) and Amino Acid Score. Shahidi, F. (1994) found the quality of shrimp proteins (PER value 2.79-2.88) to be superior to that of crab shells (PER value, 2.30-2.42).

Large portion of these by-products are underutilized or wasted or discarded (Sachindra and Mahendrakar, 2015). Dumping of these byproducts not only results in loss of large amount of bioactive rich materials but also leads to pollution problems. Recycling of these by-products into marketable products can be a solid waste management strategy. Treated fish waste can have multiple applications such as ingredient in animal feed, for the production of biodiesel/biogas, cosmetics (collagen), enzyme isolation and soil fertilizer (Sachindra and Mahendrakar, 2015). Fish waste (byproduct) can be utilized for human consumption (e.g. mince, roe, fish heads, nutraceuticals), agricultural or allied uses (fish hydrolysate, fertilizer, compost) and non-nutritional uses (biodiesel and fuel, chitin and chitosan, caroteniods pigments, leather and gelatin) (Marsh and Bechtel, 2012).

Fish Production

Total global fish production in 2016 was 171 million tonnes (MT) (marine capture fisheries: 79.3 MT + freshwater capture fisheries: 11.6 MT + aquaculture: 80 MT). Out of which 151.2 MT was directly consumed by humans as food. Amount of production lost to spoilage or thrown away after landing and prior to consumption was 46.17 MT (27 % of all landings). In 2016, 20 million tonnes (approx., 12 % of total fish production, 171 MT) was used for non-food purposes globally. Out of which, 15 MT is reduced to fishmeal and fish oil and the rest 5 MT is largely utilized as material for animal feed, as bait, in pharmaceutical uses and for ornamental purposes (SOFIA, 2018). Today, Norway has developed modern processing facilities to manage over 0.65MT of seafood by-products each year and the Norwegian Atlantic salmon industry utilizes around 90% of its byproducts. In Vietnam, Pangasius by-products are well separated and directed to specific industries for value addition (Stevens, et.al. 2018). Stevens, et.al. (2018) also advocated the strategic utilization of aquaculture by-products using Fish In: Fish Out (FI:FO) concept. A responsible and sustainable use of fish resources, whether from capture fisheries or from aquaculture, foresees an efficient utilization of the whole fish including the use of the various by-products generated throughout the processing stage".

Fishery By-products

"By-product" indicates something that is not regarded as an ordinary saleable product but can be used after treatment and the term "waste" refers to products that cannot be used for feed or food but have to be composted or destroyed (Suresh and Prabhu, 2012).EC regulation on animal byproducts (EC No.1774/2002) defines animal byproducts as whole or parts of animals or products that is not fit for and intended for human consumption. Though co-products, co-streams, discrads or waste are synonymously used, the term waste seems to mean the material has no value (Sachindra and Mahendrakar, 2015). There are different terms such as "by-product," "co-product," "fish waste," "fish offal," "fish visceral mass," "fish discards," and so on that are applied to describe the non-edible parts of seafood processing (Suresh and Prabhu, 2012). Stevens, et.al.(2018) defined the term by-products as all the materials, edible or nonedible, left over following the preparation of main products. For finfishes, typical byproducts include trimmings, skins, heads, frames (bones with attached flesh), viscera (guts) and blood. Stevens, et.al.(2018) reported the fractions of byproduct as percentage of total wet weight of atlantic salmon: Viscera (12.5%), Heads (10%), Frames (10%), Skins (3.5%), Blood (2%), Trimming (2%), Belly flap (1.5%). Moreover, table 1 shows the percentage of finfish processing by-product fraction out of total weight of fish (Suresh and Prabhu, 2012).

Potential Use of Fish Waste or Byproducts

Very recently, biotechnological processes such as biocatalytic and fermentation processes have emerged as an integral part of seafood processing; they serve not only as an attractive alternative to chemical, physical, and mechanical methods in the processing of seafood by-products, but also as tools for recovering various valuable components (Suresh and Prabhu, 2012). Biotechnological processes are well recognized as eco-friendly processes which provide a possibility to recover additional useful components other than the target component from the raw materials (Suresh and Prabhu, 2012). Various other valuable components extracted from fish waste and their application have tabulated in Table 1. Table 3 shows Potential Bioactive/ Valuable Components from Processing By-Products of Finfish. Shellfish Processing By-Products with their potential Valuable/Bioactive Components have been detailed in Table 4 and table 5.

Table 1: Percentage of finfish processing by-product fraction out of total weight of fish

(Suresh and Prabhu, 2012)

By-products	Head	Gut	Skin	Bones	Trimming
Percentage of by-products	14–20	15–20	1–3	10–16	1–5

Table 2: Valuable components and the utilization of fish by-products (Stevens, et.al. 2018)

By-Product	Valuable components	Utilized as
Heads	Proteins, peptides, lipids, collagen, gelatine, minerals including calcium, flavour	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food, nutraceuticals, cosmetics
Frames (bones, flesh, fins)	Proteins, peptides, lipids, collagen, gelatine, minerals including calcium, flavour	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food, nutraceuticals, cosmetics
Trimmings	Proteins, peptides, lipids	Food, fish meal, fish oil, food grade hydrolysates, animal grade hydrolysates, pet food
Viscera	Proteins, peptides, lipids, enzymes such as lipases	Food grade hydrolysates, animal grade hydrolysates, fish meal, fish oil, fuel, fertilisers
Skin (with belly flap)	Collagen, gelatine, lipids, proteins, peptides, minerals, flavour	Fish meal, fish oil, cosmetics, food, fish meal, nutraceuticals, cosmetics, leather, fuel,fertilisers
Blood	Proteins, peptides, lipids, thrombin & fibrin	Fuel, fertiliser, therapeutants

Table 3: Potential Bioactive/ Valuable Components from Processing By-Products of Finfish

(Suresh and Prabhu, 2012)

Category	Bioactive components	By-products
Enzymes	Proteolytic	Fish gut
	Collagenolytic	Fish gut
	Lipases	Fish gut
Flavors	Finfish flavor	Gut, head, frame
Functional ingredients	Cartilage	Head, fin, and skeleton of shark
	Chondroitin sulfate	Shark cartilage
	Fish bone	Fish frames and bones
	Fish oil and lipid	Gut and head
	Collagen and gelatin	Head, skin, fin, scales, bones, cartilages
Micronutrients	Calcium	Fish bones
	Other minerals	Fish bones
	Vitamin	Fish oil
Nutraceutical	Lipid	Gut and head
	Omega-3 oil	Fish oil and lipid
	Biopeptides	Various by-products,protein hydrolysates
	Cartilage	Head, fin, and skeleton of shark
	Chondroitin sulfate	Shark cartilage
	Squalene	Shark liver oil
	Collagen and gelatin	Head, skin, fin, scales, bones, cartilages
Active pharmaceutical ingredients	Omega-3 oil	Fish oil and lipid
	Chondroitin sulfate	Shark cartilage
	Squalene	Shark liver oil
Biofuel	Biodiesel	Fish oil, gut, head
	Biogas	Gut, head
Biomaterial/biopolymer	Chondroitin sulfate	Shark cartilage
	Collagen and gelatin	Head, skin, fin, scales, bones, cartilages

Table 4: Shellfish Processing By-Products with their potential Valuable/Bioactive Components

(Suresh and Prabhu, 2012)

Sources		By-products	Percentage of byproducts	Valuable bioactive components
Crustacean	Shrimp/prawn	Head, shell	65–85	Chitin, chitosan, *N*-acetyl chitooligosaccharides, chitosan oligosaccharides, *N*-acetyl-d-glucosamine, d-glucosamine, pigment protein, protein hydrolysate, enzymes, flavor
	Crab	Back shell, viscera, gills, claws shell	60–70	Chitin, pigment
	Lobster	Head, shell	Up to 60	Chitin, pigment, flavor
	Krill	Head, shell	71–74	Chitin, pigment, protein, hydrolysate, oil
	Crayfish	Head, shell	Up to 85	Chitin, pigment, oil, flavor
Molluscs including cephalopods	Scallop, clam, oyster, mussel, etc.	Shell, nonedible body part	60–80	Protein hydrolysate, enzyme, flavor
	Squid	Ink bag, gladius or pen, liver, other organs	25–32	Chitin, enzymes, bioactive peptides, collagen, gelatin
	Octopus	Intestine, mouth apparatus, eyes	10–20	Collagen, gelatin
Coelenterate and echinoderm	Sea urchin	Shell, viscera		Collagen, gelatin
	Sea cucumber	—	—	Protein hydrolysate, bioactive, collagen, gelatin
	Jelly fish	—	—	Protein hydrolysate, collagen, gelatin

Table 5: Potential Bioactive/Valuable Components from Processing By-Products of Shellfish

Category	Bioactive components	By-products
Enzymes	Chitinases	Prawn liver, shrimp processing waste water
	Lipase	Shellfish by-products
	Transglutaminase	Shellfish by-products
	Polyphenoloxidase	Shellfish by-products
	Alkaline phosphatase	Shrimp by-products, shrimp processing waste water
	Lysozyme	Scallop by-products
	Chlamysin	Clam viscera
	Hyaluronidase	Shrimp processing waste water
Pigment	Carotenoid (astaxanthin)	Crustacean by-products
Flavors	Shellfish flavor	Lobster/crab/crayfish/clam by-products
Functional ingredients	Chitin and chitosan	Crustacean head and shell, squid pen
	Chitin and chitosan oligomers	Crustacean head and shell, squid pen
	N-Acetyl-d-glucosamine and d-glucosamine	Crustacean head and shell, squid pen
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid Exumbrella and mesogela Shell of sea urchin
Micronutrients	Calcium	Exoskeleton of various shellfish
	Biopeptides	Protein hydrolysates
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid; Exumbrella and mesogela Shell of sea urchin
Active pharmaceutical ingredients	Carotenoid	Crustacean shell
	N-Acetyl-d-glucosamine	Crustacean shell
	Collagen and gelatin	Outer skin and cartilaginous tissues of cuttlefish, octopus, and squid; Exumbrella and mesogela Shell of sea urchin

Future

There is an increased demand for complete utilization of the abundant fish processing by-products not only as untapped sources of bioactive molecules but also to minimize the related environmental issues (Suresh and Prabhu, 2012) and thereby the future of fish processing waste for its utilization and bioconversion is promising with the right state of mind and interest. The fish processing industry and related stakeholders can intervene and make progress in future in terms of resource mobilization, value addition, product diversification and sustainable growth.

Conclusion

Fish processing waste or by-products have vast potential for their utilization. It is possible to recover the bioactive components and molecules using appropriate technologies and recent technological advances. Presently, the utilization of biomolecules have come a long way and have received an increased interest from many researchers across the globe. Literatures are available for the process which can be applied for easier processing and recovery of bioactive components and biomolecules from some of the prospective fish processing by-products or waste. However, the technical feasibility does not necessarily translate into economical feasibility and therefore, a fish processor should critically review by-product utilization options before committing to a specific process.

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