Overview of Waste Generation in Fish and Shellfish Processing Industry

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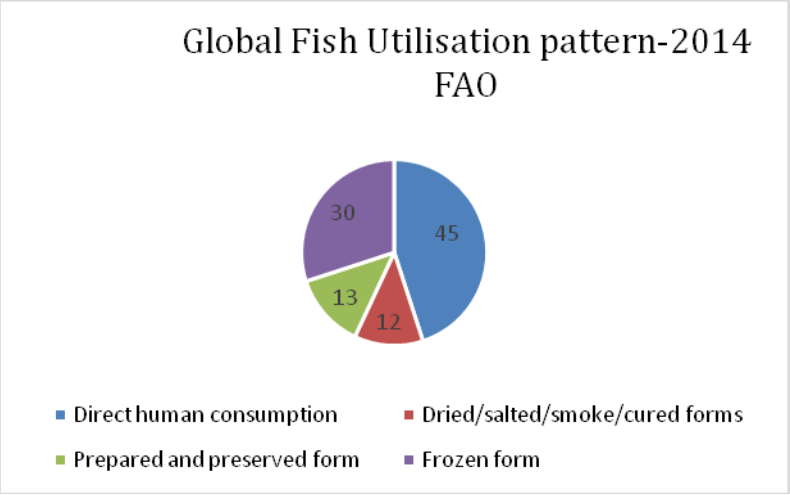
Introduction

Global fish production has witnessed a remarkable growth in recent past (excluding aquatic plants) reaching 167.2 million tonnes in 2014, with 93.4 million tonnes from capture and 73.8 million tonnes from aquaculture. A parallel development was observed in the share of world fish production utilised for direct human consumption from 67% in the 1960s to 87%, or more than 146 million tonnes, in 2014. Historically, fish has been considered as an important food source and even today it is one of the most traded commodities in international markets. Interestingly, about 15% of the world requirement for animal proteins is being met from fish alone which accounts to 4–5% of the calculated minimum requirements for protein (Guerardet al., 2005). The estimate in 2013, indicated a slightly higher value of 17% which account to 6.7% of all protein consumed (Seafish, 2014). However, there are growing concerns about the sustainability and management of seafood industry, in parallel with the increasing global demand for seafood. Recent reports project a figure of US$ 50 billion as the loss from seafood sector every year, due to poor management of available resources. Wastes are generated at different points in the value chain, viz. by-catch, onboard handling, landing centres, transportation, storage, retailers, and consumers. 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 100 mMT, and in the Indian scenario it is >4 mMT. It is estimated that fish processing waste after filleting accounts for approximately 75% of the total fish weight. This figure is too high before the challenging task of feeding the 9 billions of world population by the middle of this century.



Waste and By-products: Global Terminologies

In literature, quite often by-products, waste, discards etc are cited as alternate terms. However, a cleardistinction between by-products that can be used for human

consumption and waste / discards / viscera is made in regulatory papers (Rustad, 2003). The term 'waste' includes the remnants that cannot be recycled or converted to another high value products, and have to be composted, burned or destroyed (Bekkevold&Olafsen, 2007). On the other hand, the term 'by-products' refers to the left outs that are not generally regarded as conventional marketable products, but can be converted to industrial or edible products. Whereas, the EC regulation on animal by-products (ECNr 1774 / 2002, 2002), adopted on 3 October 2002, definesanimal by-products as whole carcasses or parts of animalsor products not intended for human consumption; by-products intended for human consumptionis not included in this definition. There are several other terms in usage to alternatively represent the by-products,such as waste via co-products or co-streams etc. Lately, as more and more research evidences were mounted on the potential biomolecules derived from marine sources, especially from fish other than meat part, there is a raising tendency to treat these as raw material rather than 'discards/waste'. Consequently, the term 'rest raw material' and 'secondary raw material' is the newly evolved expression today to highlight the importance of treating these materials as equivalent to 'targeted product'. For instance, fish skin is a rest raw material, whereas collagen is a by-product.

Global waste generation Profile

In seafood industry, the general understanding is that the edible meat part constitute forms the 'main product' and the remaining parts including head, trimmings, skin, viscera, scale, bone etc. are considered as 'left over', now as 'rest raw material/secondary raw material'. In a different angle, this perception is a bit ironical. This becomes more apparent, when a global estimate of waste generation profile is taken in to account. The amount of waste generated from seafood sector begins at the site of harvest itself. For the last few decades, the FAO estimate on postharvest losses in seafood sector remains to be 20-35% of the catch, at various stages of value chain. Approximately, 17.9 to 39.5 million tonnes of whole fish is discarded each year by commercial fishing operations. Apart from the quality losses in the supply chain, worldwide, around 130 million tonnes of fish waste is produced each year, which is approximated to more than 75% of total fish production. Normally in capture fisheries, a considerable portion of marine catch is dumped back to the sea, either as untargeted catch or as 'discards' in the case where on-board processing activities are carried out. Generally, bulk of demersal catch is processed on board. As the waste material is rarely landed onshore, a considerable proportion (11%) of the total capture biomass is disposed of at sea, mainly in the form of viscera and heads. This figure may be a bit less in the case of culture fisheries.

Table 1: Waste generation during industrial processing of fish in India

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

Nature and composition of secondary raw materials from seafood industry

The nature and quantum of secondary raw materials generated in seafood industry depends on several factors, which may be broadly categorised into resource related factors and process related factors. The former category includes species, size, age, biological nature (including presence of toxins and allergens) and morphological features. Generally, 40-70% of original raw material is discarded in commercial processing operations depending on intended product, style of dressing, type of handling (manual/ mechanical), skill of handling person, intended use and to a greater extent on the quality of raw material. Largely, seafood processing operations generate both liquid and solid wastes; solid waste being the bulk ranging from 30% to 65% of the weight of the landed fish. Head, viscera, skin, fin, swim bladder, bone, frame meat, dark meat, scale, gills, shells (crustacean, mollusca), cephalopod pen, ink sac etc. are the major components of solid waste. The liquid effluents mainly consist of blood, slime, mucus, wash off and other soluble. In surimi processing, soluble proteins are washed off to a greater extent during repeated water washing steps

Table 2: Typical composition of secondary raw materials from fish processing operations

Waste Component	% of whole fish	Active component
Head	15 - 25	Protein, PUFA, Minerals, Plasmalogens, GAG
Frame Meat	~10% of frame	Protein
Skin	3 - 5	Protein
Scale	6 - 7	Protein, Minerals
Bone	8-10	Protein, Minerals, Chondroitin
Viscera	5 - 12	Protein, Enzyme, fat
Gill	4-5	Protein, Fe

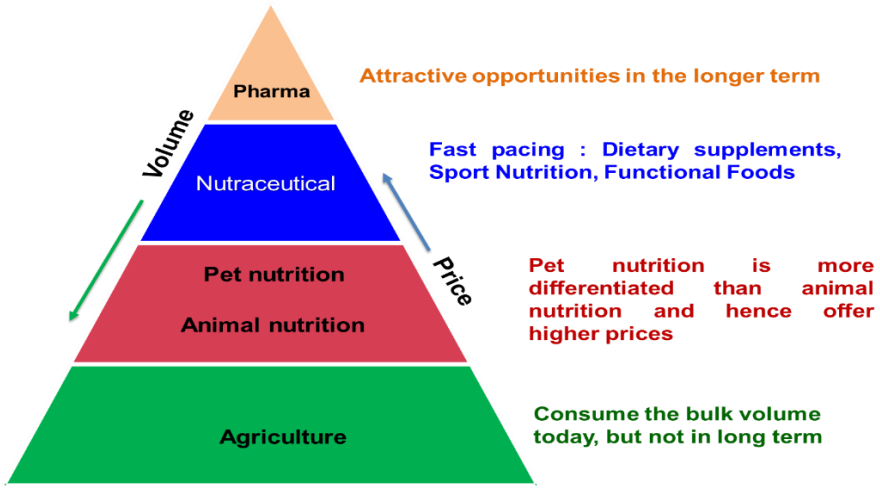
Global utilisation pattern of secondary raw materials

Presently, a major portion of the discards and low value catch, mainly pelagic varieties, are going for the production of fish meal and oil, which accounts to as much 30% of the world's total catch. A significant, but declining, proportion of world fisheries production

is processed into fishmeal and fish oil thereby contributing indirectly to human consumption when they are used as feed in aquaculture and livestock raising. As per FAO projection, by 2025, fish meal produced from fish waste will represent 38% of world fish meal production, compared with 29% for the 2013 to 2015 average level. Apart from fishmeal, a reasonable portion is going for fermented products such as fish sauce and silage. Norway is the main producer of fish silage that is used almost entirely for feed. A meagre portion is used for human consumption, to the tune of maximum 10%.

Value addition options and opportunities

Generally, two different methods, mass transformation and sorting, have been developed to improve the economic value of fish wastes. Mass transformation involves the conversion of fish waste into a single product. Sorting enables the production of specialised products such as liver oil, gelatin, omega-3, protein containing sports food and drinks, calcium, cosmetics, and pharmaceuticals. Wider acceptance and adoption of both methods could lead to significant reductions in wastes going to landfill and reduce the damaging impact of fish wastes on the environment.



Pyramidal representation of opportunities in the utilisation of secondary raw materials

Legislatory framework and Regulatory norms

As secondary raw materials are heterogeneous mixtures of a number of biomolecules, there are several EU and national regulations and recommendations internationally concerning the norms for pathogens, toxins, allergens and biogenic amines in products, particularly for those intended for man and animal nutrition. The major ones are listed below.

- EC **Disposal, Processing and Placing on the Market of Animal By-products Regulations** (SI 257, 1994) that 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 European Parliament and of the Council of 3 October 2002 laying down **health rules concerning animal by-products not intended for human consumption** (amended by Commission Regulation (EC) No

808/2003 of 12 May 2003). Provides a mechanism for the reclassification of all animal by-products not intended for human consumption based on their potential risk - this will drive fish waste utilisation and disposal options in future years.

- Commission Regulation (EC) No. 811/2003 on the intra-species recycling ban for fish, the burial and burning of by-products and certain transitional measures provides additional clarification of Regulation (EC) No. 1774/2002 as follows:
  - ✓ Derogation to permit the feeding of fish with processed animal protein derived from bodies/parts of bodies of the same species. However this is academic, as a) it does not apply to feeding farmed fish with processed animal protein from farmed fish of the same species and b) doing this is already voluntarily banned by the feed industry.
  - ✓ Wild fish and by products from wild fish may be used for the production of fish feeds or directly as a feed.
  - ✓ Fish and animal by-products intended for feed for fish must:
    - Be handled and processed separately from other material
    - Originate from wild fish or non-mammal sea animals caught for the purpose of fish meal production or from fresh by-products from wild fish processed for human consumption
    - Be packaged after treatment and clearly identified appropriate for feeding of fish.
- A draft Commission Regulation SANCO/2153/2003 implementing EC Regulation No 1774/2002, approves six additional means of disposal or uses of animal by-products, including (i) alkaline hydrolysis, biodiesel production and combustion of animal fat in a thermal boiler for the treatment and disposal of Category 1 material, as well as (ii) the processes of alkaline hydrolysis, high pressure high temperature hydrolysis, high pressure hydrolysis biogas, biodiesel production, Brookes gasification, and combustion of animal fat in a thermal boiler for the treatment and use or disposal of Categories 2 or 3 material.Fish by-products do not arise in Category 1.

Table 3: Categorisation of Animal By-Product Materials

(Source: https://www2.gov.scot/Publications/2005/03/20717/52862)

Category	Raw material	Storage and disposal requirements
1	• All body parts affected by TSE, pet/zoo/circus animals, experimental animals. • Wild animals suspected of being infected with disease communicable to humans or animals, • Animals containing residues of	• Incineration • Processing in an approved Category 1 processing plants • For certain marked non-TSE material, may be buried in approved landfill sites

	environmental contaminants; • Animal material collected when treating waste water from Category 1 processing plants • Mixtures of Category 1 material with either Categories 2 or 3 materials or both.	
2	• Fish farming mortalities • Animal by-products containing digestive tract or manure components • Animal material collected from treating waste water from slaughter houses or Category 2 processing plants • Products containing residues of veterinary drugs and contaminants listed in Group B(1) and (2) of Annex I to Directive 96/23/EC • Non-Category 1 by-products from non-member States. • Animals or parts of animals that have been slaughtered for human consumption, inc those killed to eradicate an epizootic disease • Mixtures of Category 2 material with Category 3 material	• Incineration • Processing in an approved Category 2 processing plants • Certain marked material may be (i) used as an organic fertiliser, (ii) transformed in a biogas plant or (iii) buried in approved landfill sites • For material of fish origin, may be ensiled or composted (subject to approval). • Where authorised, used as a feed for zoo, circus, fur animal, hounds, maggot / worm (as bait)
3	• Parts of slaughtered animals for human consumption • Fish or other sea animals (exc. sea mammals) caught in the open sea for the purpose of reduction to fish meal • Fresh fish by-products from plants manufacturing fish products for human consumption.	• Incineration • Processing in an approved Category 3 processing plants • Used as a raw material in pet foods • Transformed in a biogas or composting plant • For material of fish origin, may be ensiled or composted • Where authorised, used as a feed for zoo, circus, fur animal, hounds, maggot / worm (as bait)

Table 4: Categorisation of Aquaculture By-products

Source: SEERAD, pers. comm., 2004

Source of Waste	Waste Category		
	1	2	3
On-farm mortalities			
- where no disease has been confirmed		✓	
- where controls have been applied because of the presence or suspected presence of notifiable disease		✓	
- as a result of jellyfish attack		✓	
- as a result of algal bloom		✓	
- as a result of adverse weather conditions		✓	
- due to a compulsory slaughter notice		✓	
Mortalities at the processor			
- where the fish are dead on arrival		✓	
- show clinical signs of disease and are not processed		✓	
Processing waste			
- where source is subject to disease controls (but fish show no clinical signs of disease)			✓
- where source is not subject to controls			✓

- The Animal By-Products Regulations, 2003 provides a recent (October 2003) enactment of Regulation (EC) 1774/2002 (and the subsequent Regulation (EC) 811/2003 mentioned above). This Regulation recognises the ability to utilise fish by-products (primarily Category 2) for zoo, circus, fur, certain dogs (e.g. hounds) and maggot farming under approved circumstances. In addition, the burning or burial of animal by-products is permitted in certain remote areas, so long these sites are monitored at regular intervals.
- EC 1999/31/EC Landfill Directive: requires Member States to reduce the quantities of biodegradable wastes to 35% of 1995 levels by 2020. This will inevitably encourage alternative disposal techniques, such as composting and incineration.

- UK Animal Protein Regulations (2001): prohibits the use of mammalian protein (with certain specified exceptions) to ruminants and the feeding for mammalian meat and bone meal to all farmed livestock.
- UK Environmental Protection Act 1990: prohibits the keeping, treatment or disposal of waste on land unless a waste management licence has been granted for that purpose.
- UK Food and Environment Protection Act (1985): controls the disposal at sea through strict licensing. This order allows the unlicensed disposal of fish wastes at sea, even after landing its catch. However the disposal at sea from processing onshore is not permitted without a licence.
- UK Food Hygiene (Fishery Products and Live Shellfish (Hygiene) Regulations 1998. Sets out the conditions under which fish and shellfish products must be produced in order to be placed on the market. Includes provision that:
  - ✓ Offal and viscera must be kept separate from products intended for human consumption
  - ✓ Onshore processing facilities must regularly remove waste from the processing area
  - ✓ Containers holding waste material must be water tight, corrosion-resistant and be designed to facilitate cleaning and disinfection
  - ✓ Waste material held overnight must be housed in a designated area
- The Fur Farming (Prohibition) Act 2002 prohibits the farming of animals solely or primarily for their fur
- UK Integrated Pollution Prevention and Control Regulations (2000): lay down measures to reduce the emissions to air, water and land from a range of activities including food processing. Affected business need to prove that the best available techniques have been introduced to reduce the environmental impact of its operation.
- UK Landfill Tax Regulations (1996): levy charges on waste disposed of in landfill sites and thus encourages waste minimisation and maximisation of recycling opportunities. Waste is either classified as inactive/inert and other - the latter attracts a higher tax rate per tonne.
- UK Waste Management Licensing Regulations (1994): permits a number of unlicensed exemptions for waste disposal, including the spreading of shell on agricultural land and the use of shell for land reclamation or improvement. Such unlicensed disposal must be registered.

Future market trends

The market for high-end by products from marine sources is fairly high, especially for nutraceutical and medical field. The market demand for high quality oil for functional foods alone is projected to be doubled in next five years (Skjævestad& Vogt, 2009).As of today, the actual market potential of marine biomolecules has not been fully realised. Even though the marine proteins are known to have superior nutritional quality index in terms of amino acid composition and bioavailability, meagre effort is put towards protein isolate or hydrolysate production, except for a few stakeholders in Western and

European markets. There is huge demand from health and sports nutrition industry for high quality proteins and peptides, where marine proteins could be ideally place in. The market for sports nutrition products is growing with 5–7% per year. Apart from marine oil and protein, several bioactive ingredients from process discards have entered beverage market as functional and medicinal supplements. These are primarily, chitins, pigments, taurine, squalene, proteoglycans, polyphenols, probiotics, polysaccharides, enzymes, vitamins and minerals. These bioactive molecules offer innumerable health benefits, including anti-oxidant, anti-arthritic, anti-hypertensive, anti-bacterial, anti-carcinogenic, anti-obese, and anti-inflammatory activities.

Challenges and way backwards

The key to successful seafood waste utilisation and management is to develop appropriate eco-friendly reprocessing technologies that can convert all the valuable components present in the waste into valuable products and reduce the amount of waste going to disposal route. However, there are many challenges that must be overcome to achieve this goal.

1. Consumer awareness and education is a major challenge. Without consumer acceptance of food waste reduction approaches, no sustainable eco-friendly food waste utilisation and management strategy can succeed. This demands proper extension efforts from the research and extension organizations.
2. Seafood sector is a poorly organised sector. Highly scattered nature of seafood processing operations (across domestic market and processing facilities) poses problems in collection and processing.
3. Seafoods are highly perishable in nature owing to its unique richness in terms of protein, peptides, enzymes and microbial flora. This quite often leads to the mass resistance from public in starting up a business venture in the vicinity.
4. Stringent legal and environmental restrictions from the regulatory bodies as seafood waste is not categorised as “inactive/inert” waste is a major discouraging for the entrepreneurs to invest upon this resource
5. Inappropriate cold chain management from the source of generation to the point of conversion as the processors are least interested to invest further on discards
6. There is no baseline data on the availability and economics of production collected over the past years, which poses uncertainty about economics and market demand of secondary products
7. Lack of clear legal classification of secondary products in the international market is yet another major challenge to the investors
8. Lack of unified protocols for quality assurance (such as HACCP) for secondary products leads to frequent rejections from the buyers

Strategies for future development

- Strengthening the baseline data (waste generation, local facilities, current disposal plan, major stakeholders etc)
- SWOT analysis accommodating regional disparities for the development of an economically and ecologically sustainable waste management plan

- Improve public awareness on fishery waste value addition options through effective extension efforts
- Establish locality-specific value chain routes covering waste generators (Market, peeling sheds etc), regional producers (SMEs, SHGs etc), and user groups (farmers, dealers etc.)
- Networking & establishing inter-industrial linkages between potential stakeholders (Timely follow-up and review of the efforts undertaken is a must)
- Develop mobile pilot technological platforms for testing and demonstrating different technologies
- Public-Private-organisational partnership (incubation centres for pilot production)
- Public policies and legislations against waste dumping
- Framing policies for better use of fishery wastes(such as coupling of licensing of markets and processing facilities with waste conversion measures taken at the source of generation)
- There are bigger challenges with regard to clinical testing, documentation, standardisation andquality, which need to be addressed in a greater way

Suggested Readings

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