



# Is Marine Waste a Boon or Bane? An Insight on Its Source, Production, Disposal Consequences, and Utilization 11

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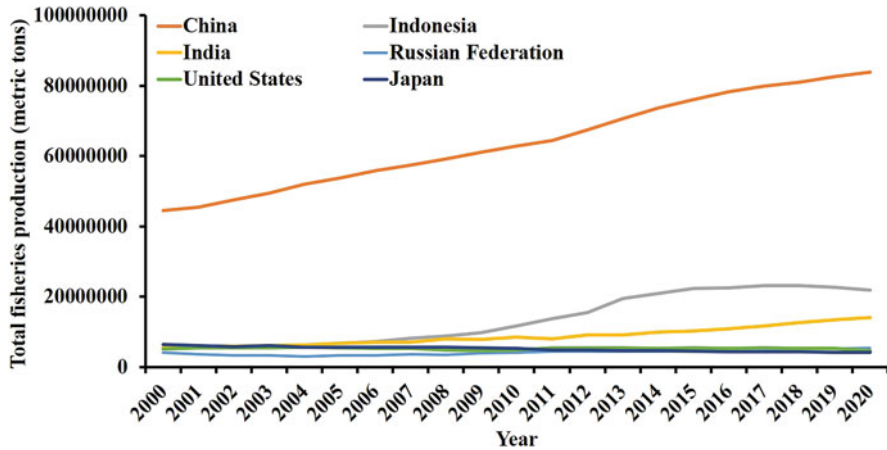
## Abbreviations

ASC	Acid soluble collagen
BOD	Biological oxygen demand
EPA	Environment protection authority
FPC	Fish protein concentrate
FPH	Fish protein hydrolysate
PSC	Pepsin soluble collagen
TSE	Transmissible spongiform encephalopathy
TTX	Tetrodotoxin

## 11.1 Introduction

Fish is consumed as a good source of protein and other vital nutrients by millions of people around the globe. Consumption of fish over the years has increased dramatically such that more than 3.2 billion people relied on fish for over 20% of their protein requirement during the year 2016 (Zhou 2017). According to past 20 years data, the maximum production of fisheries is found from coastal regions like China, Indonesia, and India (as mentioned in Fig. 11.1). India has seen a massive jump in the amount of seafood being consumed especially between the years 1990 and 2010. To cope with the increasing demand for fish and other seafood, the farming of

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**Fig. 11.1** (Source: <https://data.worldbank.org/indicator/ER.FSH.PROD.MT>)

marine organisms has boomed over the past few decades (Rao 2010). The increase in the consumption of seafood has resulted in the generation of high amounts of waste; more than 27% of the captured fish are either thrown away or rot before they can be sold (Ryder 2018; Kruijssen et al. 2020). Whole fish and shellfish are rarely consumed; most people only consume the flesh (40%), while the discard bones, shells is roughly 60% of total weight (Agustin et al. 2021). India being one of the largest fish-producing nations, generates 2 metric million tonnes of fish waste annually according to a survey conducted. The data on fish waste generation in the major coastal cities of India showed that Mumbai (22.60%) is the largest contributor followed by Chennai (15.10%) and Goa (12.50%) (Ahmad and Bhuiambar 2019). The improper discard of these wastes causes pollution to the surrounding environment and disrupts the coastal ecosystem. The waste management process can be best optimized by proper disposal or finding a specific utility for it. For finding an economically valuable purpose of the byproducts, it is very important to know the source of fish waste production (Bozariis 2014; Munari et al. 2016).

## 11.2 Sources of Fish Waste Production

### 11.2.1 Aquaculture and Fisheries

The fisheries industry is dependent on two major forms of fishing: (i) capture fisheries and (ii) aquaculture. Capture fisheries consist of the traditional form of catching fish in the wild while aquaculture is an advanced technique which involves building enclosures for the fish, crustaceans, mollusks, and aqueous plants in the water bodies. The fish in these enclosures are given high protein and other nutrient feeds which enhances their growth rate (Ryder 2018). However, this comes with a

consequence of impact on its surrounding environment, when an attempt to produce a higher number of fish per unit area is made. The attempt for increasing profits must be made in accordance with the amount of waste that can be managed to make the process sustainable. Thus, the fish must be fed according to its size, digestibility, excretion, and other health and physiological factors to ensure an optimal growth process (Bowyer et al. 2012).

The fish which are unable to survive the culture process accumulate as solid waste or suspended solid waste. This accumulation could alter the physiochemical balance of the aquaculture including biological oxygen demand (BOD) and chemical oxygen demand, which would further degrade the habitability of the aquaculture. Due to the high BOD of the fish waste, it is imperative to perform timely rectification to avoid health hazards in the aquacultures and oceans (Dauda et al. 2019). The environment protection authority (EPA) in Victoria, Seychelles has tested fish wastes and has declared them safe for biological decomposition under controlled conditions. They can be used for land applications after being subjected to appropriate treatments, irrespective of their shape and size as they fall under prescribed industrial waste. Thus, these waste materials can be processed in a designated composting facility after acquiring EPA Works Approval and License. The composting facility is built in proximity to the aquaculture if it has optimal leachate, odor, moisture, and surface run-off conditions (Venugopal 2021).

### 11.2.2 Seafood Industry

The seafood industry usually discards inedible components like skin, fins, bones, and scales as waste. These components however can be used for the production of value-added products. Organs like liver, gills, and kidney are highly susceptible to contamination by toxins like tetrodotoxin (TTX) and conotoxin, a powerful neurotoxin, which makes them unsuitable for consumption and are thus usually removed from seafood to avoid seafood poisoning (Saravanan et al. 2009; Lago et al. 2015; Schneider et al. 2018). Consumption of crustaceans such as crab, shrimp, and lobster gives rise to an enormous amount of shell waste (Joshi et al. 2020). It has been estimated that annually about 6–8 million tons of shell waste are being produced in the world out of which, Southeast Asia itself accounts for about 1.5 million tonnes, which is an alarming amount of waste (Yan and Chen 2015). Despite having high amounts of calcium, carbohydrates, and proteins, they are not considered to be of much value and are sold. Currently, these wastes are being utilized for the production of microparticles used for various applications including anti-inflammatory drugs, chitin production, and auxiliary fertilizer or as a component of animal feed. A large amount of research is being carried out to value chitosan as a natural biopolymer and its potential to be part of high-quality bioplastic (Hamed et al. 2016).

### 11.2.3 Fishing Harbors

Fishing harbors are one of the highest accumulators of fish waste for two main reasons: (i) during transportation of fish from harbor to market, fish and other marine organisms are accidentally dropped, resulting in random displacement of fish and fish remnants all around the harbor; (ii) the damaged fish are thrown either back to the ocean or in the harbor shore (Balde et al. 2020). The vendors are also known to sell only the edible part of the fish to the customers, and throw the inedible parts in their vicinity which can lead to the accumulation of fish offal and blood water waste (Fig. 11.2). This can produce an unpleasant sight and odor, degrading the esthetic value of the place. Mostly, the damaged fish are collected for animal feed. But, due to high yield per day, fish waste continues to be dumped in the harbor area, though disposal of that high level of waste is a difficult task (Read and Fernandes 2003).



**Fig. 11.2** Images of fish waste dumped in fish harbor in Royapuram Coast, Tamil Nadu

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## 11.2.4 Industrial Fish-Based Processes

Many industries using fish and other marine organisms generate huge amounts of semi-processed marine waste. This includes fish and shrimp processing units subjected to chemical treatments like calcium hypochlorite, or cleaning using soaps and detergents (Mathew et al. 2021). Each part is processed separately according to its specific needs for the products they are capable of synthesizing. The carcass of the fish is rich in meat, processing of which is first started by the removal of swim bladder, which has no significant contribution to human diet. Other parts like skin, bones, etc., are separated from the edible parts and are processed separately for production of leather and other valuable products. As a result, a huge amount of waste is generated when only the essential parts of the fish and other marine organisms are used (Sasidharan and Mathew 2011; Willis et al. 2018). The fish and shrimp processing units generate wastes which are released in nearby water bodies creating an imbalance in various parameters like BOD, suspended solids, etc., and thus polluting it and making it unfit for use (Dauda et al. 2019).

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## 11.3 Classification of Fish Waste

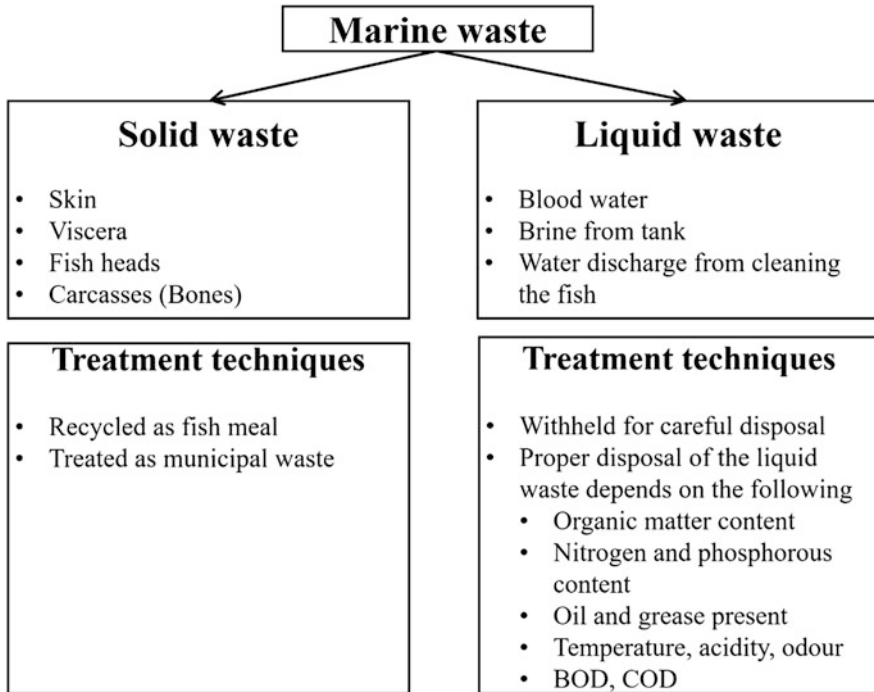
Marine wastes can be categorized as solid and liquid waste; both solid and liquid wastes have their respective problems and disposal issues. The following flowchart (Fig. 11.3) explains the classification of marine waste along with their method of treatment/disposal. Aquaculture waste is categorized into three categories 1, 2, and 3 ranging from the highest to lowest risk, respectively. Waste disposal is carried out under strict regulations to prevent any health hazard. Category 3 consists of the fish that are caught for the sole purpose of being converted to fish meal or other by-products (Sharp and Mariojouis 2012). These are of least harm to the environment, but still require licensed facilities containing the proper apparatus for disposal. Mortalities that are not caused by intentional slaughter for human consumption are classified as Category 2, these should be disposed of through legal disposal routes. Fish and other marine organisms affected by communicable diseases belong to Category 1, posing the highest risk and require appropriate disposal methods (Dauda et al. 2019; Miller and Semmens 2002). Table 11.1 describes all the categories of aquaculture/fishing waste:

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## 11.4 Waste Treatment

### 11.4.1 Primary Waste Treatment

The main objective of primary treatment is to remove the large sized solid particles that either float on the surface or settle at the bottom. It involves treatment of the wastewater using three basic physical processes. (i) Screening: Screening involves passing the liquid through a sieve-like structure, through which solid particles are



**Fig. 11.3** Classification of marine waste

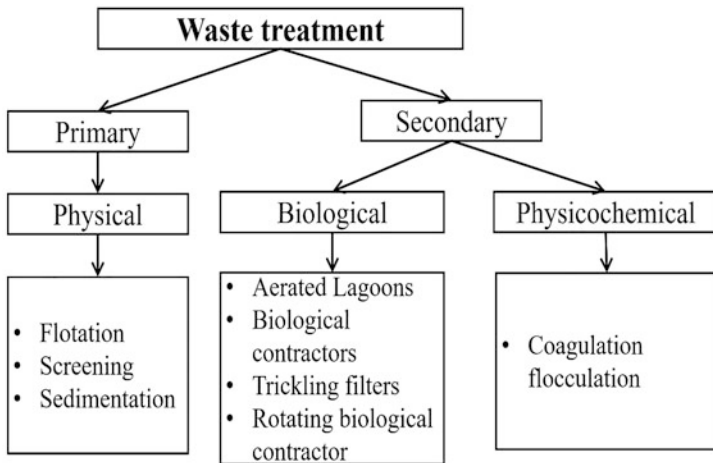
trapped in the sieve, while the liquid flows out. The size of the sieve can be changed depending on the size of particles present in the liquid. (ii) Sedimentation: Sedimentation is the tendency of particles to settle in a solution. Particles settle due to the difference between their density and that of the solution. Higher density particles settle while lower density ones remain afloat. This concept is very useful in the removal of solid particles present in a liquid solution. (iii) Flotation: As opposed to sedimentation, during flotation particles float over the liquid surface (Fig. 11.4). These suspended or lower density particles can be collected and removed (Cristóvão et al. 2014).

### 11.4.2 Secondary Waste Treatment

It involves the use of microbes for the degradation of wastewater. This is done through the usage of aerobic as well as anaerobic microbes for efficient treatment of the waste. Aerobic microbes digest the organic matter in the presence of oxygen to release carbon dioxide along with biomass, while anaerobic microbes produce methane, carbon dioxide, and water. Following this, the physicochemical process (Coagulation-flocculation) utilizes substances known as flocculants/coagulants to

**Table 11.1** Categories of fish waste and their disposal

Category	Raw material	Disposal
1	All body parts affected by TSE (transmissible spongiform encephalopathy) Containing traces of environmental contaminants Suspected of being infected with diseases communicable to human or other animals	Incineration processing in approved category 1 processing plants buried in approved landfill sites
2	Fish farming mortalities (routine mortalities or catastrophic mortalities) Mortalities where the fish are dead on arrival mortalities where the fish show clinical signs of disease On-farm mortalities where the fish have died due to either a harmful algal bloom, jellyfish attack, adverse weather condition	Incineration processing in category 2 processing plants. The raw material can be ensiled or composted and used as feed for other animals
3	Fish or other sea animals caught in the open sea are meant for the purpose of reduction to fish meal Fresh fish by-products from plants manufacturing fish products for human consumption	Incineration used as raw material in pet food ensiled or composted



**Fig. 11.4** Waste Treatment Processes

cause aggregation of the particulate matter to form “flocs” which then settle down (Mack et al. 2004).

## 11.5 Fish Waste Disposal

The importance of organized fish waste management is increasing due to concern over health and sanitation issues. Fish waste which is disposed and circulated improperly can lower the oxygen levels in water bodies and as water decomposes it leads to foul odor. Small-scale fish industries produce around 20–80% of fish waste (Islam et al. 2004; Arvanitoyannis and Tserkezou 2014).

### 11.5.1 Fish Disposal Treatment Methods

They are classified mainly into two different types: traditional fish waste disposal and anaerobic digestion as illustrated in Table 11.2. Traditional methods are the conventional methods which are used to dispose of fish waste (Arvanitoyannis and Kassaveti 2008; Green and Mattick 1977). These methods have major drawbacks and are not commonly used.

### 11.5.2 Anaerobic Treatment

Fish canning industries produce a large amount of anaerobically digested solid waste. Most of this solid waste can be used to produce methane in reasonable amounts. Research has shown that anaerobic digestion and co-digestion of fish waste has significant potential for bio-methane production (van Rijn et al. 1995; Nges et al. 2012). Fish waste has seen very limited use as substrate in anaerobic digestion due to two major issues: (i) variable composition (up to 60% protein, 20%

**Table 11.2** Traditional/conventional fish waste treatment

Technique name	Description
Landfill	Technique employed for disposal of waste by burying under soil
Ocean dumping	Dumping of waste into the ocean. An easy and ineffective disposal method
Direct feeding	It involves feeding the animals dried and ground fish waste to increase the nutritional value of the feed
Minced-based products	Mince products are prepared using either whole fish or gutted fish. Fish mince finds application in several foods like fish finger, cutlets, etc.
Incineration	The process of incineration involves combustion of the sample containing organic material. It converts the sample to ash, flue gas, and heat
Ensilage and land injection	Liquefied products made from either whole fish or gutted fish by the action of the natural enzymes present in the fish along with added acid. The ensiled fish can then be injected into the land



fat, calcium and hydroxyapatite from bones and scale, palmitic acid, mono-saturated acids); (ii) release of high quantities of ammonia as a result of fish waste digestion inhibits digestion of the substrate and can also result in the accumulation of volatile fatty acids. In contrast, co-digestion has been found to be a suitable option to overcome these issues by increasing the organic content of the substrate through the addition of another substrate, such as cow manure, water hyacinth, and sisal pulp (Boziaris 2014; Mshandete et al. 2004).

## 11.6 Utilization of Marine Waste

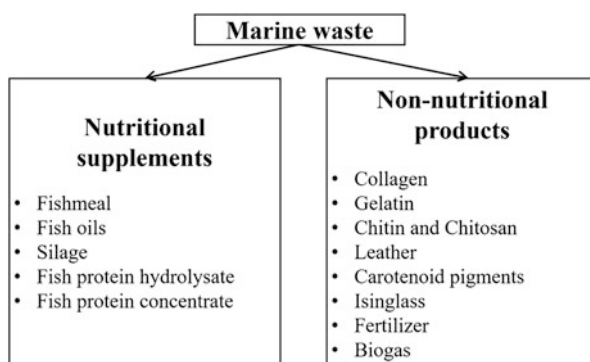
As previously stated, the incorrect disposal of marine waste leads to many disagreeable circumstances. Thus, there is a need for novel techniques for the utilization of waste to produce useful products (Fig. 11.5). Utilization of marine waste can be of two broad categories: (i) for the production of nutritional supplements or consumable products, and (ii) non-nutritional uses (Plazzotta and Manzocco 2019; Radziemska et al. 2019).

### 11.6.1 Nutritional Supplements or Consumable Products

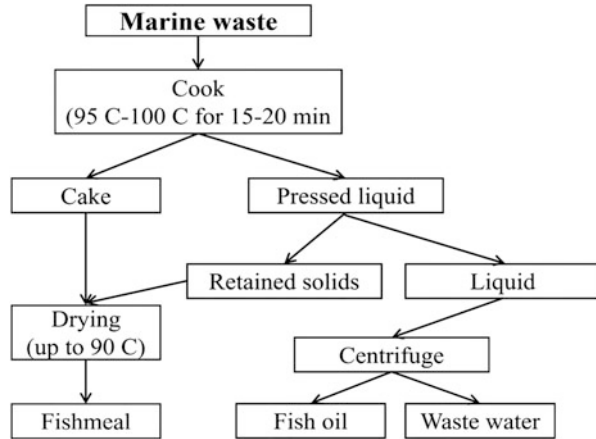
#### 11.6.1.1 Fishmeal and Fish Oils

Fishmeal is commercially used nutritive feed for aquaculture and farm animals. It is a powdered product produced from fish waste or whole fish of any species through drying and grinding which are generally not used for human consumption. When combined with fish oil, it is a rich source of protein, vitamins, and essential oils (Han 2015). The production of fishmeal is initiated by pressing cooked fish waste or fish, yielding a cake and the removed liquid. This cake along with any remaining solids, which can be separated from the removed liquid, is dried to produce the fishmeal. This liquid is then subjected to centrifugation to separate the oil from water (Fig. 11.6). The oil thus obtained can be further processed and sold commercially as fish oil (Das et al. 2011; Mo et al. 2018).

**Fig. 11.5** Utilization of marine waste



**Fig. 11.6** Production of fishmeal

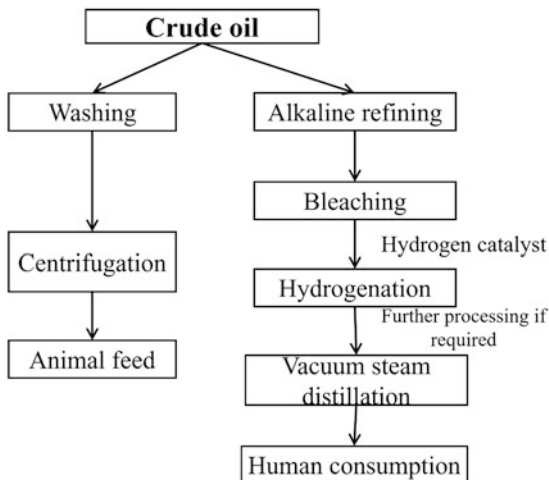


Fish oils are of two types: Oil present in the muscle of the fish and the oil present in the visceral mass of the fish including the liver. It is also possible to extract fish oils from the heads, fins, and scales in fish waste (Aidos et al. 2001). During fishmeal production, the crude oil obtained consists of both muscle and visceral oil components which are then purified and used in aquacultures or for bulk production of products such as margarine, ink, and rubber. They have also been used in the treatment of hide in leather production. Products such as cod liver or shark liver oils are most commonly used due to their high content of omega-3 fatty acids, Vitamins D and A (Bockisch 2015). Crude oil obtained during fishmeal production is washed and centrifuged for usage in animal feed followed by purification if it is intended for human consumption. The process begins with alkaline refining to prevent the rancidity of the oil during storage, followed by the removal of the clear layer formed upon settling of the mixture. Following this, bleaching of the oil is carried out to remove undesirable fatty acids and pigments. Hydrogenation is then carried out using hydrogen in the presence of a catalyst (Fig. 11.7). In succession, vacuum steam distillation is carried out to remove more volatile compounds and stabilize the flavor of the oil (Archer 2001).

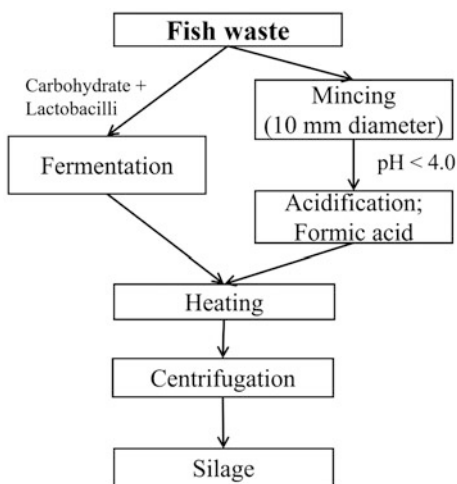
### 11.6.1.2 Silage

Fish silage is a liquid product used in animal feed similar to fishmeal due to its high nutritious value. It can be produced from any type of fish or from fish waste through low value, relatively inexpensive fish that are generally used for the production of silage. Silage can be produced through the enzymatic digestion of fish waste or through the addition of acid for degradation (Ke et al. 2017). Production of fish silage by acid digestion consists of four main stages. The first stage involves the rupture of cells to release intracellular enzymes through mincing of the fish. This is followed by acidification of the sample using 3.5% Formic acid, though mineral acids can be used as cheaper alternatives. This addition of acid initiates the production of the silage which is enhanced by intermittent mixing (Fig. 11.8). The last two

**Fig. 11.7** Production of fish oil



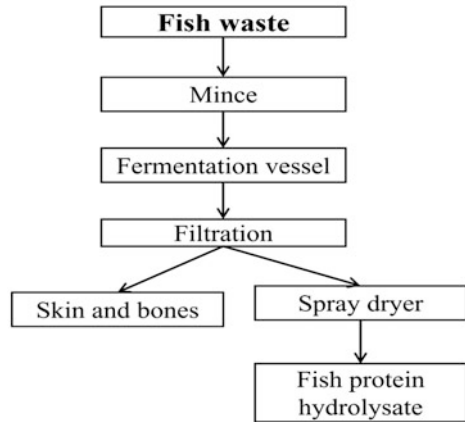
**Fig. 11.8** Production of silage through acid digestion and enzymatic degradation



stages of the process are removal of oil from the silage through heating followed by centrifugation (Arruda et al. 2007).

Silage production through enzymatic digestion involves the addition of an inexpensive carbohydrate source and lactobacilli to the fish waste. The bacteria cause acidification of the system by converting the sugars to lactic acid while simultaneously producing additional products associated with the deterrence of spoilage. This mixture is then incubated at 25–30 °C and the oil is removed through the same processes as silage produced by acid digestion. The major drawback of silage is the inconvenience faced during its transport (Ghaly et al. 2013; Olsen and Toppe 2017).

**Fig. 11.9** Production of Fish Protein Hydrolysate



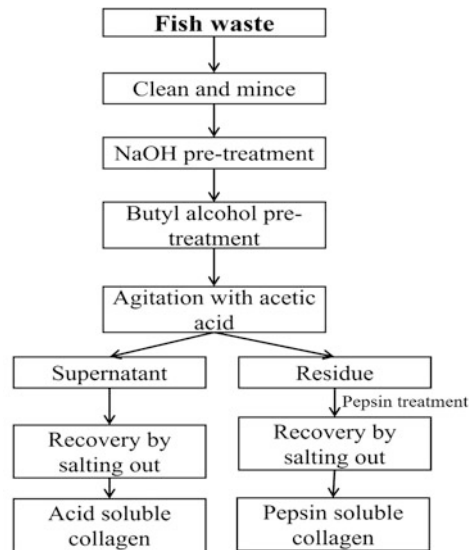
### 11.6.1.3 Fish Protein Hydrolysate (FPH)

FPH is a powder produced by proteolytic digestion of fish to yield amino acids of numerous lengths as mentioned in Fig. 11.9. It is used in animal feed or as an emulsifying agent due to its high gelling and whipping properties (Kristinsson and Rasco 2000). The production of FPH is either through an autolytic process or through the addition of external proteolytic enzymes, i.e., accelerated hydrolysis (Balde et al. 2021). While the autolytic process depends on the enzymes of the fish itself, accelerated hydrolysis is generally preferred as there is no interfering enzyme activity. The autolytic process is time-consuming and involves the breakdown of peptides over a period of time ranging between a few days to a few months. Preservative agents such as organic acids or salts are added to prevent spoilage (Rustad and Hayes 2012; Yoshida et al. 1999, 2003). FPH production using external enzymes involves the mincing of the fish waste followed by agitation with the addition of a commercial protease (Rustad et al. 2011). Optimum conditions for the protease activity are then maintained through the addition of an acid or alkali and maintenance of temperature. The resultant broth is then filtered and spray-dried for commercialization (Anal et al. 2013). FPH may also be utilized further for the production of bioactive peptides and proteins showing various biological activities (Narayanasamy et al. 2020).

### 11.6.1.4 Fish Protein Concentrate (FPC)

FPC is a powder similar to FPH which is intended for human consumption. It is often used to increase the protein content of food or even as a food product in itself (Ahmad et al. 2019). The FPC is of three grades: Type A, B, and C. Type A FPC is used in a variety of edible products such as biscuits, bread, and soups while Type B is used as a nutritional supplement in some Asian countries. Both are manufactured through a multistage solvent extraction method followed by the removal of fats and odor components. Type C FPC is produced through a more hygienic fishmeal process (Archer 2001).

**Fig. 11.10** Production of collagen



## 11.6.2 Non-Nutritional Uses

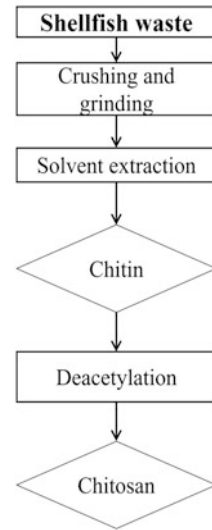
### 11.6.2.1 Collagen

Collagen is the major structural protein in the extracellular matrix found abundantly in skin, bones, and fins of fish. It is used by the food, cosmetics, biomedical, and pharmaceutical industries as well as being considered for a novel wound dressing material in the form of films (Govindharaj et al. 2019). Isolation of collagen is in three general stages: Sample preparation, Extraction, and Recovery. The fish waste is prepared by cleaning and pretreatment using an alkali-like sodium hydroxide as described in Fig. 11.10. Extraction is achieved by agitation with an acid to give acid-soluble collagen (ASC). Pepsin is also used to improve the yield of collagen; this is pepsin soluble collagen (PSC) (Sampath Kumar and Nazeer 2013). Recovery of the extracted collagen is through salt precipitation or salting out of the protein (Kumar et al. 2012; Kim and Mendis 2006).

### 11.6.2.2 Gelatin

Gelatin is a voraciously used substance in the food industry for the formation of gels, for the improvement of elasticity, and stability of food. Fish gelatin has found application in food, formation of coatings, and photograph processing (Kouhdasht et al. 2018). It is produced by hydrolysis of collagen. Fish skin is soaked in an alkali solution to remove pigments and undesirable proteins after which it is washed and soaked. The process is accompanied by continuous gentle stirring in acetic acid followed by distilled water upon swelling of the skins. The product is filtered and the filtrate is lyophilized to give gelatin powder (Nazeer and Deepthi 2013; Nazeer and Suganya 2014).

**Fig. 11.11** Production of chitin and chitosan



### 11.6.2.3 Chitin and Chitosan

Chitin is a biopolymer composed of repeating N-acetylglucosamine units that are primarily manufactured from shellfish waste. It is converted to the more stable chitosan through deacetylation by alkali treatment which is used in effluent treatment, paper, food, and cosmetic industries (Morin-Crini et al. 2019). Extraction of chitin is initiated by crushing the waste shells followed by the extraction of pigments from the shell waste using a suitable solvent to produce chitin (Fig. 11.11). Chitosan is produced by deacetylation of chitin using a strong alkali (Sudhakar et al. 2020).

### 11.6.2.4 Leather, Carotenoid Pigments, and Isinglass

Leather is made from fish skin similar to animal hide to make clothing, bags, shoes, etc. The skins of larger fish such as cod, shark, and salmon are generally preferred for the leather-making process. Fish leather is often lighter, strong, and attractively patterned and is thus becoming more prevalent in the fashion industry through prominent designer clothing brands (Duraisamy et al. 2016).

Carotenoids are pigments which contribute to the characteristic pink-red color of fish and shellfish. They are extracted from shellfish waste through solvent extraction during the extraction of chitin and are essential to aquacultures as they cannot be synthesized by the fish and thus must be taken up through food. Astaxanthin is a commercially marketed carotenoid used in aquacultures and as a nutraceutical product for the treatment of a variety of conditions including Alzheimer's disease, Parkinson's, and sunburns (Stepnowski et al. 2004).

Isinglass is a tough leather-like product sold commercially as a powder or paste. It is produced from the swim bladder of fish and is used as a common additive to beverages such as beer and in the food industry as a replacement for gelatin. Production of isinglass begins with the cleaning of the swim bladders of the fish

followed by salting for 1–3 months (Asty et al. 2018). After salting, the swim bladders are washed thoroughly and the fat-rich tissue is removed. They are then stretched out and dried in sunlight to remove all water. The innermost collagenous layer is separated from the other two layers and sundried. The product at this stage is called fish maw. This maw is moisturized in water and flattened by pressing between iron rollers to form thin sheets that is the final isinglass (Shahidi et al. 2019).

#### 11.6.2.5 Biodiesel and Fertilizer Production

Fish and other marine organisms are usually rich in fats and oil. This is the primary requirement for the synthesis of biodiesel and is a suitable alternative fuel for the current conventional sources, which is currently being rapidly depleted. Fish oil can be converted to biodiesel by suitable preliminary treatments (Ahmad and Bhuiambar 2019). Fish oils are less dense than commercially used vegetable oils, which lessens the carbon deposition and viscosity, making it a better source for biodiesel production. Ozone pretreatment is one of the most essential steps in biodiesel production. It aids in structural modifications of various types of biomasses, which would result in release of carbohydrates and other substrates for hydrolytic processes, resulting in production of biodiesel. The filtration processes are carried out in high-grade kaolin filters. The biodiesel produced is tested for various parameters like flash point, density, percentage of sulfur, etc. (Travaini et al. 2016).

The harmful side effects of synthetic fertilizers has encouraged the development of new innovative organic fertilizers. A mixture of agricultural waste and fish waste has proven to have very good nutritional properties and rapid degradability, which makes it a good alternative component of fertilizers (Radziemska et al. 2019). Though this application is only recently put into research spotlight, it has been traditionally used as fertilizers by Native Americans, using Herring fish. This technique can be proven to be very useful, especially in islands and remote coastal areas, where access to commercial fertilizers is bleak. Any fertilizer must essentially have NPK elements, i.e., nitrogen, phosphorus, and potassium, respectively. Apart from this, they should enable the soil to regenerate other minerals in the required proper ratio. Amalgamation of fish waste and seaweed was proven to be a good fertilizer after being tried in North-west Spain coast plantations (López-Mosquera et al. 2011). This way, we can get rid of seaweed and also improve crop yield. The fertilizer was synthesized by composting for months together, to derive the required nutrient ratio, enzyme degradability, moisture, and various other parameters. Fish waste has also proven to improve the C to N ratio of soil. As the proteins in the fish remains start degrading on burial, the essential nutrients, nitrogen and carbon get released into the soil. It is important that before being brought to use, it must be subjected to phytotoxicity tests (like root growth inhibition) and derive clearance. However, it must be noted that fish fertilizers are notorious for attracting animals like bear and raccoons. Thus, it should be buried deeper in the soil, or completely avoided if there is any risk of these animals (López-Mosquera et al. 2011).

## 11.7 Conclusion

Fish consumption has rapidly increased over the years, which has led to a complementary increase in fish waste accumulation as a large percentage of fish is inedible. Various sources of fish wastes have been identified including poorly maintained aquaculture, fisheries, and inedible fish remnants from seafood industries. Harbors are also a site of fish waste accumulation, degrading their esthetic value. Industries release untreated or partially treated fish wastes in water bodies leading to a decline in its quality index. Waste segregation practices are gradually being adapted based on the treatment and disposal methods used. The most commonly practiced disposal techniques include acid hydrolysis and anaerobic digestion. Various traditional methods of waste disposal have been put into practice including landfills, ocean disposal, incineration, direct feeding, and its usage in silage and mince-based products. Currently, this waste is used for the production of commercially valuable products. Mostly, nutritional values are tried to be exploited by making fishmeal for aquaculture and farm animals, extract vitamins and omega-rich oil, preparing silage, fish protein hydrolysates for commercial purposes, and fish protein concentrates which are used in edible products. Non-nutritional products like collagen, gelatin, chitin and chitosan, leather, fertilizer, biodiesel, isinglass, and carotenoids are also extracted from fish waste and can solve various environmental issues.

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