Fish Waste as a Potential Feed Ingredient for Fish Meal Production

S. M. M. S. Afreen, S. L. Rasmiya Begum, S. M. M. S. Himaya, and M. S. M. Imthiyas

Abstract The fisheries and aquaculture sector has increased production in present, however, the products aren't utilized to their full economic potential, leading to the generation of waste. Disposal of seafood wastes because of not only substantial environmental pollution but also a loss of the prospective value of such goods stressed the prominence of finding suitable modalities to manage fish waste. The experiments have explored, that being a main source of protein, minerals, and vitamins, fish waste could be converted to fish meal as it is the costliest source of protein. Fish meal is one of the most valuable byproducts of the marine industry that isn't used for human food and can be utilized as a feed ingredient not only for fish but for other animals too. On the other hand, production of fish meal is challenged due to lower catch from capture fishing, increased cost, and put forward to utilize the alternative sources for fish meal production. Fish byproducts are employed in the creation of fish meals to address these difficulties and could reduce fishing pressure on meal-targeted species. Accordingly, the book chapter discusses elucidating the utilization of fish waste and byproducts as a source for fish meal production, factors influencing the production, and merits and demerits addressed by the production and how those can be overcome.

Keywords Animal feed · Byproducts · Environmental pollution · Immunity · Fish meal · Fish waste management · Nutritive value · Processing · Protein source

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1 Introduction

The fishing industry not only provides necessary food but also has the potential to bring in money for the government. Additionally, it can produce a range of waste, such as solid, liquid, and gas disposal (Jayathilakan et al. 2012). More than half of fish muscles, comprising, skin fins, heads, viscera, and filleting frame are thrown as "wastes," according to valuations. Every year, global fisheries throw-outs surpass 20 million tons, accounting for 25% of total marine fishing catch production (Caruso 2016). Discards include fish processing wastes, "non-target" species, and byproducts. Most fishermen do not use the waste from fish capturing and processing as a side product of their fishing business. If these waste materials are not dealt with, they contribute to pollution, community problems, and the spreading of illnesses like cholera. (Krishnamoorthy 2018), so fish waste management by converting them into valuable products has received attention.

Fish meal (FM) is the most valued byproduct of the marine sector due to its protein source (Gutasi 2021). For farmed fish meals, it is the greatest nutritional and digestible element (FAO 2018). It has a good essential amino acid (EAA) composition and nutrient digestibility is pleasant and is widely available. The manufacturing of aqua feeds has a substantial impact on total production costs; on average, one kg of fish meal needs four to six kg of fish (Shepherd and Jackson 2013). Due to the usage of an expensive protein source, fish meal, feed expenses represent more than half of overall aquaculture production costs (Coyle et al. 2004). The fishing industry consumes around 60% of the world's total fish meal production each year, and this percentage is likely to rise in the future to support future aquaculture expansion (Tacon, Hasan and Metian 2011). Several fish nutritionists have been working to find new strategies to lessen the demand for fish meals. As a result, fish byproducts and wastes should be turned into fish meals to remedy the problems. Meanwhile, by forming feed from these undesired goods, the value of the fishery byproducts could be raised to a lesser level (Ferraro et al. 2010).

The sections that follow describe how fishing wastes and byproducts are utilized in the creation of fish meals, the importance of fish meals, the factors that affect fish meals, and recommendations in this context.

2 Fish Waste and Byproducts

The processing of fish before it is sold results in the production of byproducts. In presence stands not any universally accepted delineation of fish byproducts. Typically, we refer to heads, viscera, bone, cut-offs, skin, and fish that are injured or unhealthy for human intake, as well as by-catch. Byproducts are well-defined in Norway as goods that are not considered to be normal profitable goods (round, fillet, and beheaded fish), but could be reused after treatment (Bergman 2015). The term "waste" refers to products that must be composted, burned, or otherwise destroyed since they cannot be used for feeds or value-added products. (Bergman 2015). The number of byproducts accessible is estimated differently. Only 40% of fish goods used by humans are generated by the entire fish industry, with the remaining 60% consisting of unwanted byproducts (Dekkers et al. 2011). 9.1 million tons of fish waste are thrown away annually, according to United Nations Food and Agriculture Organization (FAO) (Pérez Roda et al. 2019).

Fish byproducts vary in composition and stability, an excellent source of lipid, protein, and other worthwhile components like nucleic acids, calcium, phosphorous, and bioactive compounds. In particular, fish skin is high in protein, especially gelatin and collagen, trimmings and bones are high in calcium, and the head, intestines, and bones are high in lipids (Kandyliari et al. 2020). The average protein content of fish byproducts ranges between 49.22 and 57.92% by dry weight, the ash content is 21.79–30.16%, and the fat content is 7.16–19.10%(Abbey et al. 2017).

Fish byproducts vary due to species, the extent of process, and environmental conditions because, each has a distinct and unique composition, size, and form, (Rustad et al. 2011). The processing of edible fish produces discards that primarily consist of heads (9–12%), skin and fins (1–3%), muscle trimmings (15–20%) viscera (12–18%), bones (9–15%), and scales (5%) (Martínez-Alvarez et al. 2015). Byproducts are classified into two broad categories based on their potential for spoilage and degradation. The first group of easily degradable byproducts includes fractions containing high concentrations of various endogenous enzymes while the second group includes more steady byproducts such in place of skin, heads, and bones (Rustad et al. 2011). The amount of fish byproducts available is enormous, and there are a lot of opportunities for different value-added goods to be made from this raw material.

3 Value-Added Fish Products

Waste and byproducts generated during fish processing aren't used to their full economic potential and possibly can be transformed into valued products such as fish meal, collagen, fish oil, silage, fish protein hydrolysate (FPH), etc. This creates a positive economic and environmental impact, allows for the viable usage of fish means, and increases the accessibility of beneficial marine proteins and lipids for the world's growing population. This section of the chapter briefly summarizes the value-added products that have been developed so far utilizing fish waste and byproducts. Each has its pros and cons (Coppola et al. 2021).

Fish meal: It is the more promising product available and an increasing trend is noticed for fish meal production from fish byproducts over several decades, where it is estimated to be about 1.5 million tonnes by 2030 (Guenard 2021). Several scholars have addressed the process of making fishmeal out of fish byproducts and waste (Ockerman and Basu 2014; Pagarkar et al. 2014; Masagounder et al. 2016).

Fish protein hydrolysates (FPH): These are the waste products produced when fish proteins are enzymatically broken down into small peptides with 2–20 amino acids. FPHs are also used as milk alternative for people as well as an animal feed and fish-based fertilizers (Pagarkar et al. 2014).

Fish oil: These are primarily composed of triglycerides of fatty acids, phospholipids, wax esters, and glycerol ethers (Afreen and Ucak 2020). The high interest in fish oil stems from the fact that it possesses two important Polyunsaturated fatty acids (PUFA) containing eicosapentaenoic acid and docosahexaenoic acid known as omega-3 fatty acids. These two most common PUFA are used as food complements and in the production of biofuels (Coppola et al. 2021).

Fish silage: In order to create this product, whole fish or leftover fish components are mixed with acids, enzymes, or microbes. Fish enzymes are used to carry out this process. Even on a large scale, fish silage is a low-cost and simple technique. It reduces industry odor and drainage issues. It also has the disadvantage of being a high-volume product that must be consumed at the same location where it is produced (Afreen and Ucak 2020).

Collagen: It is a prevalent structural protein that is complicated. Fish collagen absorbs into the body more efficiently and has a higher bioavailability (up to 1.5 times) than collagen from pigs and cows (Pagarkar et al. 2014). It's a fantastic functional molecule for the food, makeup products, biomaterial, pharmaceutical, and nutraceutical industries. The development of a strategic extraction technique for commercial exploitation is the primary challenge with the utilization of fish collagen (Martínez-Alvarez et al. 2015).

4 Fish Waste to Fish Meal

(i)(i) Fish meal

Fish meal has historically been employed as the main protein source in the aqua feed business, due to its high protein level and well-balanced essential amino acid (EAA) profile, (El-Sayed 2020). It is a dry, brownish grey, fine to a coarse powder. Fish meal is made by drying whole fish, fish byproducts or fish trimmings, to remove 90 to 95% of the water and grinding them into a powder (Krishnamoorthy 2018). One-third of the annual global catch of fish is utilized as raw resources for fish meal production; these are sustainable catches with no direct human consumption outlet (Barlow 2003). The nutritional composition of the fish meal is made up of protein (70%), fat (9%), water (8%), minerals (10%), and vitamins, reliant on the type of fish utilized (Afreen and Ucak 2020). In practice, fish meals have been divided into four categories: herring type, anchovy/pilchard, menhaden, and white fish (Ockerman and Basu 2014).

Fishmeal, with the biological value due to its richness in EAAs, mainly lysine and sulfur amino acids which the animal body cannot produce, makes itself an unrivaled feed constituent. In addition, the inclusion of FM in a well-balanced diet compensates for amino acid deficiencies in vegetable proteins (Pagarkar et al. 2014). FM is used in the manufacturing of feed for fish, ruminants, crustaceans, poultry, pigs, and

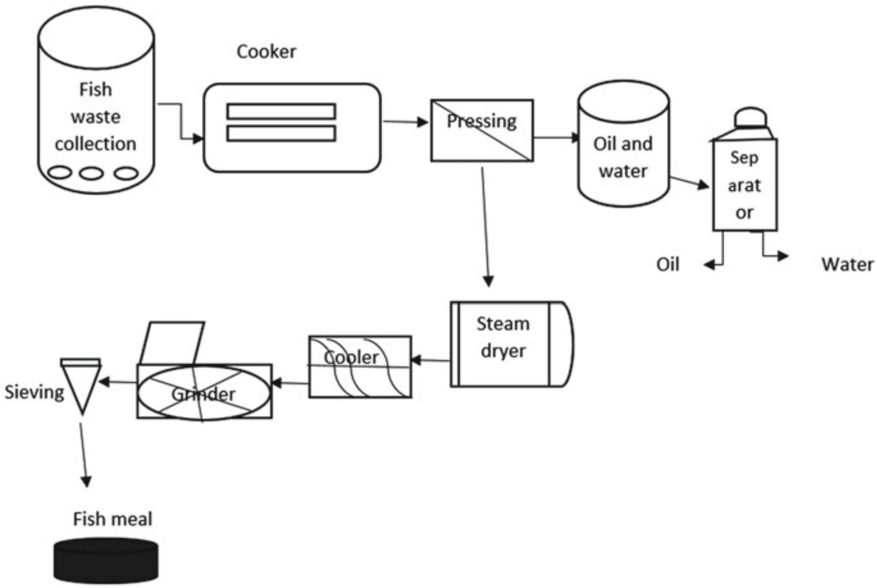

Fig. 1 Main unit procedures of fish meal

companion animals. This FM is combined with other components to make animal feed (Masagounder et al. 2016).

(ii)(ii) Manufacturing Process

The primary goal of FM production is to remove moisture from raw fish to less than 10%. The oil content of the FM must not exceed 10%. There are primarily two methods for producing FM known as wet and dry reduction, where the first one is widely utilized to produce the majority of the FM around the world. FM production comprises various manufacturing processes as indicated below (Fig. 1).

Cooking

Cooking for around 15 to 20 min at a temperature of 95 to 100 ° C, is used to coagulate fish proteins and rupture the cell walls of fish tissues, which aids in the parting of oil and water in fish. The most popular technique is to constantly convey the fish through a steam cooker, it continuously conveys it (Nissen 2003).

Pressing

Just after cooking, the mass is pressed to remove water level up to 45–55% and oil 2–3%. A single screw press or a double screw press can be used for pressing, whereas the latter one is preferred more because it removes the most oil and moisture from cooked fish. A mixture of water, oil, and solids is squished through the press perforations and later separated; the solids, water and oil are brought back to the press cake at the end of the press, and the separated oil is refined and stored as a separate product (Gunn 2003).

Drying

The press cake is then introduced into a drier either direct (cylindrical drum) or indirect (steam-jacketed cylinder or a cylinder with steam-heated disks), along with the retrieved solid particles and the stick water concentrate, to reduce the moisture level to 10% to make the product stable. The drying process can be accelerated by raising the temperature. There are, even so, certain critical limits to avoid quality loss, particularly of protein. When using the machinery and environmental conditions typical to the fishmeal business, the temperature of the drying material must not rise above 90 °C in order to preserve the nutritional value. Currently, large-scale fish meal producers hardly ever employ direct dryers. To eliminate steel impurities, the dried press cake is put through a magnetic separator (Krishnamoorthy, 2018).

Cooling

In the cooler, dried FM is chilled to room temperature.

Sieving

Prior to grinding, dry press cake is put through a vibrating screen to remove extraneous components including wood, fishing hooks, cloth, and nails.

Milling

Fish meal with small particles is produced by grinding.

Packing

Fish meal is typically packaged in jute bags lined with polyethylene (PE). The outside packaging is then labeled properly. Fishmeal storage must be moisture-proof. (Marvin et al., 2019).

(iii)(iii) Merits and demerits of Fishmeal Incorporated into Fish Diets

Merits

Nutritive value

Fish meal is well-known for its higher nutritive value with enriched energy, protein, minerals, and vitamins (choline, biotin, and vitamin B12, as well as vitamins (A, D, and E) contents. In addition, FM is a rich source of unsaturated fatty acids such as eicosapentaenoic acid and docosahexaenoic acid, in humans and laboratory animals, these fatty acids have a beneficial effect on autoimmune disease, heart disease, and inflammatory diseases (Simopoulos 2002). Particularly, high-quality fish meal provides between 60 and 72% protein contents by mass, making it one of the preferred animal protein additions in farm animal diets from a nutritional point of view (Cho and Kim 2011). FM with mackerel dried at 70 °C supplemented with synthetic amino acids (Lysine, Tryptophan, and Threonine) had the maximum dietary value when fed to weanling pigs until they were 29 days old. FM with mackerel matched the amino acid profile of the porcine plasma protein diet (Kim and Easter 2001).

Performance

The addition of fishmeal to animal diets improves feed efficiency and growth by improving food palatability, uptake of nutrients, digestion, and absorption (Olsen and Hasan 2012). Therefore, from 10 to 20 weeks postpartum, Holstein cows with a 5 percent FM consumption produced more milk and protein (Adachi et al. 2000). Weanling pig expansion was enhanced by replacing soybean meal in the beginning diet with menhaden FM, which also improved average daily gains, average daily feed intake, and gain/feed ratio (Stoner et al. 1990).

Immunity

The nutrients in fishmeal help to maintain a healthy functional immune system, in turn, boosting disease resistance and reducing the dependency on antibiotics and other drugs. For example, eicosapentaenoic acid in FM can help prevent cardiovascular disease and has a major effect on the retina, vascular and hemostatic systems, the brain and other body tissues (Visentainer et al. 2000).

Therefore, following an immune assault, rats' development is somewhat prevented by diets with a reasonably high n-3 PUFA to n-6 PUFA ratio (Jeffery et al. 1997). Due to the anti-inflammatory properties of n-3 fatty acids in FM, made the early weaned pigs consume more feed and fight better for disease (Cho and Kim2011). FM nutrients also aid in increasing phytohemagglutinin-induced proliferation and CD4 cell population in laying hen spleen cells (Babu et al. 2005).

Demerits

Toxicity

Being a protein-rich feed ingredient, fishmeal is subject to deterioration easily and quickly when overheated. During deterioration, amino acid decarboxylation, referring to protein retrogression generates toxic materials. In particular, a toxic substance known as gyserosinis formed during overheating of fish meal causes significant damage (ulceration) to the mucous membrane of poultry stomachs and tends to result in bleeding and vomiting (Cho and Kim 2011). Furthermore, histamine in FM causes poisoning and gizzard erosion in broilers (Pan and Yu 2014).

Expensive

The high cost of fishmeal limits its utilization as a feed ingredient. Feed expenses represent for more than half of total aquaculture outputs due to the use of such an expensive source of protein, fish meal (Gutasi 2021). The total global production of fishmeal in 2016 was 4,445,000 tonnes (Green 2016), and the price of FM has more than doubled in the recent past (Pavan Kumar et al. 2014) and it is expected to increase by 90% between 2010 and 2030 (World Bank 2013).

Environmental Pollution

Though conversion of fish waste into valuable products like fishmeal reduces the solid waste generation in the environment considerably, there is the possibility of polluting surface water. Wastewater derived from fishmeal processing plants may be disposed into water bodies which alters the water quality that becomes unsuitable for living beings and other purposes also key nutrients can leach into the body of water, causing water deterioration. Additionally, feed sediment accumulated on the seabed or pond bottom causes pollution, raising the risk of anoxia and mortality.

5 Factors Affecting the Production and Utilization of Fish Meal

Composition and type of fish

The raw materials composition, in terms of dry matter, fat, and protein determines the production rate as well as quality. For instance, the demand for fish meals produced from small, bony non-food fish species like anchovy would be high as protein supplement due to its relatively higher protein content than the fish meal produced from food fish species like mackerel. Additionally, the fat content plays a crucial role in plan as it not only forecasts oil yield but also determines if it is worthwhile to construct oil recovery systems.

Length of season

The profitability of the business depends on how many days a year the plant might have been in operation. Additionally, the longer the season, the more importance must be given to strategies for lowering variable costs and more money should be invested in initiatives that will save labor and power while ensuring higher returns and quality of products.

Economic

The production of the fish meal should be expanded to meet the growing demand and is challenged with a consistent supply of raw materials at a reasonable price, where continuous availability of fish waste and byproducts can be influenced by the seasonality of catches. Meanwhile, larger-scale production requires higher investment in terms of inputs, equipment, labor, etc.

Technical

The conventional method of fishmeal production employs many laborers which brought a challenge to production. The utilization of advanced and automated technologies though help counteract labor issue; the requirement for skilled and trained personnel remains still. There are a lot of laborers in developing countries who don't know how to maintain fish meal plants. Production plants are becoming larger, and production is being concentrated in fewer factories that combine raw materials from various sources or facilities.

Social

Aquatic meals like fish and other seafood are often regarded as healthful. The idea behind this approach is that fish includes healthy components such as highly digested proteins, marine oil, antioxidants, minerals, and vitamins. However, consumers' poor knowledge and understanding regarding the importance of marine byproducts and or value-added products and their nutritive values impede their usage at a larger scale of byproducts in commodities.

Environmental and ethical issues

The environmental and ethical issues being raised by non-governmental organizations and the media are significant, and they may have an important effect on the actual use of water resources in aqua feeds such as a fish meal. For smooth functioning, the placement of the plant in relation to homes and closed harbor is essential. Public policies safeguarding the environment from unfavorable air and water pollution are important to thoroughly review that influence the choice of equipment, factory premises, and finance required for odor abatement and wastewater emissions cleaning [6, 15, and 25].

6 Suggestions and Conclusion

Fish waste and byproducts have been found the potential to be utilized for the process of fish meals as a valorization approach to fish waste. The production of fish waste fish meals become popular over years due to their nutritional value and rather good performance compared to other feed ingredients worldwide. Though, its production and consumption fluctuate because of a lack of awareness, drawbacks, and challenges associated with, the unavailability of resources, facilities, technologies, etc. To cope with this, various measures have to be undertaken at multi-levels. Foremost, people should be made aware of the possibility of fish waste and byproducts as a constituent for FM production and its subsequent benefits. As private sectors play a key part in food and feed production, their participation has to be encouraged further at country levels to invest their capital in FM production, which requires appreciative regulations and legislation. Hence, globally, the developed countries should join hands together with developing countries to facilitate production via the provision of skilled, trained personnel, and advanced technologies. Eventually, the studies should be explored more and in-depth to evaluate the potential of fish waste-based fish meal as a feed ingredient in various aspects among different sets of animals.

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