J. Appl. Sci. Innov. Technol. 4 (2), 37-46 (2025) ISSN (Online): 2583-505X

PMSST

Journal of Applied Science, Innovation & Technology (JASIT)

Journal homepage: https://prakritimitrango.com/documents-reports-and-publications/journal/

Review article

Fisheries waste management a novel approach for technology transfer: A review

Jyoti Verma[1*], Priyanshu Kumar[2], Anamta Rizvi[1], Sailendra Kumar[1], Pooja Adwani[2], Vishwajeet[1], Jiwan Singh[2]

[1]*Department of Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow- 226025, India*

[2]*Department of Environmental Science, Babasaheb Bhimrao Ambedkar University, Lucknow- 226025, India*

ARTICLE INFOR

Article history:
Received: 23 September 2024
Revised: 27 June 2025
Accepted: 30 June, 2025
Published online: 31 December 2025

Keywords:
Fish by products
Sustainable fisheries
bioactive compounds
Omega-3 fatty acid extraction
Fish collagen
Fish silage

ABSTRACT

Fish waste is an important waste product from the fishing or aquaculture industries. It is made up of by products such as fish heads, bones, skin, scales, viscera and blood, as well as nutrients like protein, lipids and minerals. Resources made from fish waste can be used to make variety of goods. For example, high protein content can be given to livestock and aquaculture rations as value-added products, mostly from fish heads and bones. On the other hand, fish waste is a great source of omega-3 and other necessary fatty acids that are needed to produce fish oil and other nutritional goods are derived from the fish. The biochemical content of fish waste, which includes enzymes and bioactive substances, has the potential for usage in pharmaceutical and cosmetic products. Using these components not only reduces environmental impact, but also produces value-added goods that help to promote sustainable waste management practices.

1. Introduction

The fishing industry is an essential component of global economic which includes any industry or activity that takes, cultures, processes, preserves, stores, transports, markets or sells fish or fisheries products. It is defined by the Food and Agriculture Organization (FAO) as including recreational, existence and commercial fishing, as well as the related harvesting, processing, and marketing sectors (Cooke et al., 2016). The global fish production reached an estimated 179 million tons in 2018, with about 156 million tons utilized for direct human consumption(Oliveira et al., 2021).The industry provides livelihoods for approximately 59.5 million people, many of whom live in developing countries where fisheries are a crucial source of income and nutrition. The demand of seafood is increasing rapidly in India 2-4 million metric tone annually and 130 million metric ton across the global level. The need for sustainable practices in fisheries is more pressing than ever, particularly in the management of waste generated by fishing and fish processing activities (Saleh et al., 2022). The global market cost of fish waste management was 5412 million in 2023, while it may be reachedupto7,563.3 million in 2035 which will be growing at a 2.9% compound annual growth rate s(CAGR) (Fish Waste Management Market Size and Share Forecast Outlook for 2025 to 2035). In this, industrialization and urbanization period, due to demand of sustainability fish waste management will be increasing as propelling the global market.

Currently, fish waste is partially used in the production of fishmeal, fertilizers, and fish oil, though these applications often yield low profitability. Additionally, some fish waste is used directly as feed in aquaculture or is simply discarded (Islam et al., 2021). To solve environmental issues, optimize the use of biomass for high-value applications, better fish waste management is needed (Mo et al., 2018). The recent focus on fish by products' alternate applications highlights how important they are to sustainable development and economic expansion. To maximize the use of biomass for high-value

***Corresponding Author:** *Email address: jy.verma1015@gmail.com* (J. Verma)

applications and to address environmental concerns, then better fish waste management will be needed. The recent studies are focusing on finding new applications of fish waste that will be essential for sustainable development and economic expansion. Present review is focusing on various applications of fish byproducts, highlighting their potential as rich sources of valuable compounds such as enzymes, bioactive peptides, and biopolymers, which have diverse applications across multiple industries (Ozogul et al., 2021).

2. Importance of waste management

The fishing industry helps ensure a reliable supply of these nutritious as food sources (Thilsted et al., 2016).This industry provides employment and income for millions of people worldwide, including fishermen, processors, distributors, and those in supporting industries. Angling and fish item are major s fend out commodities for numerous nations, producing income through worldwide (Sumaila et al., 2016). This helps balance trade deficits and boosts economic development. Fishing industry makes a difference adjust exchange shortfalls and boosts financial development. This industry helps in ensuring food security and address malnutrition.

3. Types and composition of fish waste

Fish waste, which includes a variety of materials produced during the handling and processing of fish, it is a substantial byproduct of the fishing and aquaculture sectors. It is essential to comprehend the different types and composition of fish waste in order to create efficient waste management plans and investigate possible opportunities for value-adding. Fish waste is divided into various categories in this article, which also offers comprehensive composition information for the main constituents.

3.1. Solid fish waste

Fish processing residue is called solid fish waste. This group consists of heads of fish, which are frequently thrown away with usually having high content of fat and protein and also can contain important elements.Nutrient recovery and recycling from fishery waste can be achieved as by-products. Despite their potential for usage in high-nutritional products like fish meal or as ingredients in soups and broths, they are frequently disregarded. Fish bones, which make up a sizable amount of solid waste, and it can be turned into meal or utilized in other ways such as fertilizer or animal feed. Fish bone meal is a great soil supplement because it has especially high content of calcium and phosphorus. Mineral content of fish bone meal can be utilized as organic fertilizer development for sustainable environment. Although fish scales are usually seen as garbage, and their high collagen content makes them useful in the cosmetics and other industries. Scale collagen can be utilized to make dietary supplements and skin care products, among other things. Fins are discarded away frequently, and it can be processed to make gelatin and fish meal, among other goods. Fish gelatin made from fins is used in pharmaceuticals, food goods and photography (Shavandi et al., 2019). Viscerafish internal organs that are typically thrown away but can be used as fertilizer or animal feed due to their high nutrient content. It is moreover conceivable to extricate valuable substanceslike omega-3 greasy acids from angle viscera by handling(Santana et al., 2023)**.**When solid fish waste is improperly disposed of, it can because environmental problems like blocking waterways and depleting oxygen in aquatic systems, which can create "dead zones" that are harmful to aquatic life(Bashir et al., 2020).Oxygen is consumed during the breakdown of solid waste, which causes hypoxic conditions that are harmful to marine ecosystems. Furthermore, the buildup of solid waste in landfills can produce leachate, which contaminates neighboring water bodies and groundwater (Nagarajan et al., 2012).

3.2. Liquid-based fish waste

The fluids discharged during the washing, gutting, and processing phases of fish handling are collectively referred to as liquid fish waste. This kind of garbage is distinguished by elevated level of organic matter content organic matter, which is abundant in liquid waste, it can be harmful to the quality of water when released untreatednutrient recovery and recycling from fishery waste and by-products (Monteiro et al., 2018).

Aquatic life may be impacted by receiving waters' elevated biochemical oxygen demand (BOD) due to high quantities of organic matter. Nutrient pollution potential of liquid fish waste can cause nutrient pollution when it is dumped into aquatic settings. This can result in toxic algal blooms and the degradation of aquatic habitats. The overabundance of nutrients from liquid waste can cause eutrophication, which is characterized by an excessive algal growth that damages aquatic habitats by lowering oxygen levels (Akinnawo, 2023).

Pathogen risk may be happened if liquid fish waste is not adequately treated before being released; it may include germs that could endanger human health as well as marine life. The release of untreated fish waste into water bodies can jeopardize biodiversity of marine lives and terrestrial life as well. Liquid fish wastes include a sufficient quantity of pesticides and heavy metals (mercury, lead) which gets accumulate in marine lives, including fishes over time (Kvasnicka et al., 2019). To reduce these hazards and safeguard the quality of the water, effective treatment techniques are required.

3.3. Fish throwaways

Fish that are captured but not kept for human food are referred to as fish discards. This group consists of unwanted species during fishing operations, non-target species are caught and frequently discarded (Zhang et al., 2023). These species may include young fishes and other marine life that aren't profitable. Undersized angle that are returned to the ocean due to measure limitations are alluded to as undersized angle. Fishes that are returned to the sea due to size restrictions are referred to as undersized fish. Discarding fish that are too small might cause population decreases and upset the delicate balance of marine environments. An estimated two-thirds of all fish caught may be thrown away as waste, meaning that wasted fish can make up a sizeable fraction of the entire catch. This adds to the general waste issue in fisheries in addition to representing a loss of potential food supplies. Fish waste can have detrimental effects on the environment, such as dwindling fish stocks and upsetting marine food webs(Coppola et al., 2021).Therefore, the proper disposal of fish waste has be ensured by composting and upcycling the waste into biodiesels, animal feed and biodegradable polymers (Fig. 1).

Fig. 1 Products developed from fish waste (Nelluri et al., 2024)

Fig. 2 Proper disposal of unusable fish waste (Sumithra and Amala, 2020)

4. Occurrence of microplastics

Microplastics (MPs) have been studied and found in aquatic species, with fish, crustaceans, and bivalves being the most common food sources. The MPs levels of economically important fish species from China, the US, and Europe have been tracked and examined. Sardines and anchovies, for example, have MPs contents of 58% and 60%, respectively (Jin et al., 2021).

MPs concentrations in the fish from China's, Archipelago were found in the range from 2.3 to 7.3 items per fish. The vast majority of detections had a size of less than 1000 µm, with 17%–79% falling into this category. The materials that are regularly utilized in MPs are primarily made of nylon, PET (polyethylene terephthalate), PP (polypropylene), PA (polyamide), and PE (polyethylene).

Bivalves frequently contain MPs, with contamination levels ranging from 0 to 10.5 items/g. Compared to the oyster, the Texas mussel contained a larger concentration of microplastics. Fibers made up the majority of the MPs found in the gastrointestinal tracts of bivalves. Angle tissues with MPs included the stomach (57.7%), digestion tracts (34.6%), and the range around the gills (7.7%). MPs were identified mostly in the gastrointestinal systems of fish, which are typically discarded and hence removed from the food, according to studies done with deep-sea and river species of fish. Although they are present as MPs in the digestive systems of small fish and shellfish should be taken into account (Jin et al., 2021).

5. Composition of Fish Waste

The composition of fish waste varies depending on the species of fish and the specific processing methods employed. However, fish waste is generally recognized as a rich source of nutrients and bioactive compounds. It is making a valuable resource for various applications. This section outlines the nutritional and biochemical composition of fish waste is emphasizing its potential uses in animal feeds, fertilizers, and other products.

Nutritional composition of fish waste is rich in various nutrients; it is making a valuable resource for multiple applications. The typical nutritional composition of dried fish waste is as given in Fig. 3.

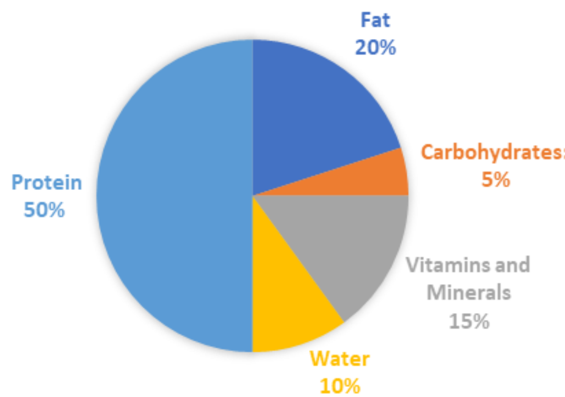

Fig. 2 Nutritional composition of fish waste (Powder form of catfish)

According to these factors, fish waste may be a significant source of proteins and fats. Because of its high protein concentration, this waste can either replace or enhance more conventional protein sources like fish or soybean meal in animal feeds. The energy density of animal feeds can also be improved by the fat content, which includes important fatty acids. The species and methods of processing that fish waste uses affect its protein content (Mo et al., 2018). Fish meal or fish protein hydrolysates, for instance, can be made from the high amounts of protein found in fish heads, bones, and viscera. Because of their bioactive qualities, fish protein hydrolysates are especially prized and utilized in functional meals and nutritional supplements. For example, compared to bones and scales, fish heads and viscera often contain higher fat contents. Ash content in fish waste was found between 21% and 30%.The majority of which is made up of minerals like calcium, phosphorus, magnesium, and trace elements (Abelson, 2022). These minerals can improve the nutritional content of fertilizers and animal feeds since they are necessary for a number of metabolic processes. Fish excrement can be added to organic fertilizers to improve soil fertility and plant growth because of its high mineral content (Khairul et al., 2025).

Table 1 Data showing the occurrence of Microplastics in fishes in different countries

Location	Species	Concentration	MPs size		Shapes	Microplastic chemicals
			Max	Min		
India (Bay of Bengal)	K. pelamis	-	5mm	0.5mm	Fragmented	PE, PP, PET, PES, PUR, PVC, and EVA
Belgium	Gobiogobio	-	80	3400	-	EVA, PP, PET, PA
U K	Rutilusrutilus	0.69±1.25 items/individual	-	<5000	Fibres, Pallets Fragments,	-
France	Squaliuscephalus	0.16 items/mg	147	479	Fibres, Fragments	PAN, PEVA
Germany	22 species	0.2-0.5 items/individual	22	4986	Fibres, Fragments, pallets	-
China	Carassius	0-18 items/individual	100	5000	Fibres, Fragments, Pallets, Films	PE, PP, PVC, Nylon

Note: Full name of Chemicals: PE: Polyethylene; PP: Polypropylene; PET: Polyethylene Terephthalate; PVC: Polyvinyl chloride; PUR: Polyurethan; PES: Polyethersulfone; PAN: Polyacrylonitrile; PEVA: Polyethylene vinyl acetate; PA: Poly amide; Nylon

6. Effects of improper fish waste disposal on the environment

The incorrect handling of fish waste can lead to serious environmental issues because of its high level of organic matter and biochemical oxygen demand (BOD). Untreated fish waste disposal can result in serious ecological harm and the depletion of priceless resources. Large scale fish production expansion has created worry for environment. Large-scale fish catchment and production generate huge amount of waste output which directly or indirectly reaches to natural environment. Fish wastes both solid and liquid has created problems and badly impacted the natural bodies and environment. Fish waste pollution has caused drastic effects on water quality, which end with jeopardizing biodiversity (Kurniasih et al., 2018). The incorrect handling of fish waste can lead to serious environmental issues because of its high level of organic matter and BOD. Untreated fish waste disposal can result in serious ecological harm and the depletion of priceless resources (Coppola et al., 2021).

6.1 Hypoxic environments and oxygen demand for fish waste generation

The high organic matter concentration of fish feces can have a significant negative effect on the BOD of aquatic habitats. Bacteria and other microbes break down the organic content from fish excrement, using up the dissolved oxygen in the water (Hlordzi et al., 2020). The majority of aquatic life cannot survive in hypoxic circumstances, which are caused by a reduction in oxygen levels. Studies have revealed that, depending on the kind and volume of waste generated, the BOD of fish processing waste can range from 10,000 to 50,000 mg/L. This high BOD suggests a high risk of oxygen depletion, which can result in the development of "dead zones" in the water bodies' areas where there is insufficient oxygen for the surviving aquatic life.

6.2 Pollution of nutrients and eutrophication

Untreated fish excrement can contribute to nutrient contamination in aquatic habitats, which can cause growing of algae and aquatic plants excessively. The term "eutrophication" refers to this occurrence, which can have detrimental effects on aquatic environments (Kapsalis et al., 2021). Excess nutrients from fish faces can promote algae growth by blocking sunlight and interfering with photosynthesis in submerged plants. Excess nutrients from fish excrement can promote algae development, blocking sunlight and interfering with photosynthesis in submerged plants (Kapsalis et al., 2021).

Eutrophication results in formation of dense blooms of noxious and foul -smelling phytoplankton. This will make the water unfit for growth and development of other aquatic life forms. Algal blooms will get formed which will block the light penetration, reduce the growth and cause die-offs of other essential plants and fishes. Due to the eutrophication process, photosynthesis increases then it will deplete dissolved inorganic carbon due to which pH of water bodies will increase to extreme levels during day time. Rise in pH causes blinding in organism that use the dissolved chemical cues for movement and survival by help of chemosensory abilities (Turner and Chislock, 2010). As the algal blooms will be died and decomposed, they consume even more oxygen, further exacerbating hypoxic conditions. Algae growth can be accelerated by the excess nutrients from the fish waste, which can obstruct sunlight and interfere with photosynthesis in submerged plants. The algal blooms' increased oxygen consumption as they deteriorate and die makes the hypoxic conditions worse (Lan et al., 2024).

The release of excess nutrients like nitrogen and phosphorus in water bodies leads to excessive growth of algae and some specific aquatic plants, thereby disturbing the aquatic life balance.

6.3 Degradation of habitat and biodiversity loss

Fish waste buildup in near-shore locations has the potential to suffocate benthic habitats, upsetting the local species and changing the structure of the ecosystem. When more tolerant species supplant sensitive ones, there may be a decrease in the diversity and quantity of species. Aquatic life may be harmed by toxic compounds like hydrogen sulfide that are produced when fish excrement decomposes.

6.3.1 Marine biodiversity loss

Fishing causes removal of biomass from water bodies that cause impacts on specific fish populations as well as non-targeted fishes in habitats. The proportion of overfish stocks has got increased by 10% in 1974 to 34% today (Bae, 2024).

The overexploitation always has negative impacts on the ecosystem and the profitability of commercial also negatively impacted, causing loss in billions of dollars. Depletion of marine biodiversity by excessive fishing also causes reductions inspecies' body size and their range. The biodiversity loss is associated with the habitat loss due to requirement of habitat for spawning and nursery ground by different small and large aquatic species. Destruction of coastal areas for human activities and construction leads to loss of habitat for reproduction and protection in early development period these include mangrove forest, seagrass meadows or coral reefs (Nichols et al., 2019).

6.3.2 Impact of fish waste on coral reefs and biodiversity

Liquid based fish waste is contaminated with a range of chemicals that gradually causes eroding of coral reefs by fueling the algal blooms, depleting oxygen and disrupting the microbial balance. Coral reefs which are also known as the 'Rain Forest of the Sea, are highly sensitive to chemical pollution. The fisheries waste leads the expulsion of zooxanthellae, the symbiotic algae that resides in the tissue of corals, imparting vibrant colors and energy to them through photosynthesis. When expelled, the coral discoloration begins leading them to become highly vulnerable to disease, starvation and death. This phenomenon is called as coral bleaching (Nama et al., 2023).Excessive fish wastes cause sediment runoff in the ocean making the light penetration difficult at bottom of sea, thereby affecting the coral polyps life forms. The nutrient enrichment indirectly effects by promoting enhanced macroalgal productivity and growth.

6.4 Impact of fishing industry on coastal life

The fishing industry and marine aquaculture involve a variety of species, rearing techniques, and husbandry methods. Extensive fishing and marine aquaculture is done by the farming of finfish or shellfish in a 'natural' habitat where no supplementary food is provided by humans. On the other hand, modern fisheries industry operates using cages or ponds where high- quality artificial fish feed and medication is provided which ultimately directly or indirectly impacts the environment like here coastal areas greatly affected due to release of organic and inorganic nutrients and release of chemicals during medication. These impacts tend to be the most severe in areas where poor water exchange (Ioannis etal., 2008). Fish farm waste affects the area surrounding the sea coast directly and it alter a wider coastal zone at different ecosystem levels, which decreases the biomass, density and diversity of the benthos, plankton and nekton, and modifies natural food webs.

7. Traditional methods of handling fish waste

Conventional approaches to managing fish waste usually include cremation and landfilling. These methods are deemed unsustainable in the long run due to their severe disadvantages.

7.1 Landfilling

Fish waste can be disposed of by landfilling. The garbage is buried in places designated for landfills. Possibility of groundwater contamination may occur if fish waste is not appropriately disposed of, it may contain high quantities of organic matter and nutrients and it could seep into the groundwater(Coppola et al.,2021).Methane gas is emitted due to breaks down of waste anaerobically in landfills. Methane is a strong greenhouse gas that plays a role in global warming. Problems with odors, fish excrement can emit unpleasant smells that can bother the neighbors around. Loss of valuable resources, fish waste landfilling is a lost opportunity to recover important nutrients and chemicals, resulting in the loss of valuable nutrients and other materials (Kumar et al., 2024).

7.2Composting

An efficient way to turn fish waste organic material into a useful product, such as nutrient-rich compost that can be used to enhance soil health and support agricultural activities(Ayilara et al., 2020). Fish waste can be composted separately or in combination with other organic materials like wood chips, sawdust, or agricultural waste to balance the carbon-to-nitrogen ratio, which is essential for successful of composting process. Fish waste includes offal, bones, and processing by-products. Numerous fruitful composting initiatives in Alaska have shown the viability and advantages of this strategy. Safe and Legal Fish Waste Composting is conducting in Alaska. For instance, several processing facilities and fisheries have put in place on-site composting systems that turn fish waste into compost and producing other useful byproduct for nearby businesses and communities (Rajeswari et al., 2018).

7.3 Incineration

Incineration is the process of reducing the volume of fish waste while potentially recovering energy (Rifath and Thariq, 2023). However, this strategy does have drawbacks such asair pollution if not managed appropriately. Incineration can emit dangerous air pollutants such as particulate matter and dioxins. High energy consumption to evaporate the moisture content from the wet fish waste, which needs a large amount of energy. The ash generated from incineration still requires proper disposal, as it might include concentrated levels of heavy metals and other toxins.

7.4 Low-value applications

Conventional applications of fish waste include fertilizers, because of its high nutrient content, fish feces are an excellent natural fertilizer. However, the application is often limited to local areas due to transportation costs and potential odor issues. Silage fish waste can be preserved with acids or fermentation to produce fish silage, which can then be utilized as a feed element(Mehta et al., 2023). However, the market for fish silage is modest when compared to the overall amount of trash created.This can pose serious environmental consequences as well, including pollution, greenhouse gas emissions, and the depletion of important nutrients and chemicals.

7.5Valorization of Fish Waste

Valorization is the process of converting waste into valuable products, thereby reducing the environmental impact and creating economic opportunities. Fish waste valorization involves extracting high-value substances and developing new products from the fish waste stream.

7.5.1 Techniques of Valorization

High-value materials are extracted and used variety of methods from fish waste:

Enzymatic hydrolysis- this method breaks down angle proteins into littler peptides and amino acids utilizing chemicals. The resulting products can be utilized in fertilizers and animal feed, among other things. Fermentationof fish waste can be done by microorganisms to produce useful substances including chitin, ethanol and lactic acid.

Supercritical fluid extraction- this technique extracts lipids and other materials using supercritical fluids, such as carbon dioxide.

Membrane filtration-valuable chemicals can be extracted and purified from fish waste streams using membrane-based techniques like ultrafiltration and nanofiltration. Fish waste can be converted into bio-oil, biochar, and syngas by the process of pyrolysis, which can be used as fuel or processed further to create various products. Through the application of valuation strategies, the fishing sector may lower waste, generate new sources of income, and support a circular and sustainable economy (Sahana et al., 2023).

7.6. High-value substances from fish waste

Fish waste is a rich source of various high-value substances that can be extracted and utilized in different industries. **Collagen-** in fish skin and bones is a good source of collagen, which has applications in cosmetics, pharmaceuticals, and food products. Gelatin fish gelatin, like collagen, can be produced from fish skin and bones and used in a variety of applications, including food, pharmaceuticals, and photography**. Enzymes-** fish waste can contain useful enzymes like proteases and lipases, which are used in food preparation, biotechnology, and medicines. **Bioactive peptides**—these molecules produced from fish proteins may be provided for health benefits such as antioxidant, antihypertensive, and immune modulatory properties. They can be employed in both functional foods and nutraceuticals. **Chitin and chitosan**- derived from crab shells, it can be processed to produce chitosan, which has antibacterial qualities and it is used in biomedicine, agriculture, and food preservation. **Omega-3 fatty acids** extracted from fish waste offer a number of health advantages and it can be used as dietary supplements. **Biofuels**- anaerobic digestion and transesterification are two methods that can be used to turn fish waste into biofuels like biogas and biodiesel (Sahana et al., 2023).

8. Current fisheries waste management

8.1 Bioremediation

When all the methods and techniques are used to bio restore a contaminated environment to its original state. Bioremediation can be done through different methods and includes organic compound, nitrogenous compounds and hydrogen sulphide as biocontrol agents (Musyoka, 2016). In aquaculture, the macroalgae and microcrustacean are widely used to separate nutrients from the fish waste (Marinho-Soriano et al., 2011). *Aspergillus awmori* is utilized for fermentation to dry minced sardine(Yamamoto et al., 2005). In future, this will be used to develop a model for processing fish waste as well as for digestibility. It has been found that the digestibility of fermented fish meal is higher than crude and raw fish.

8.2 Waste Segregation

The fisheries waste is a harmful and polluting agent for aquatic and terrestrial lives if released in raw form in the environment. It is taken as a measure to simplify the complex wastes into simpler by separating of solidsfrom liquid waste. The segregation method is a sustainable measure to minimize waste in raw processing industries. Segregation is performed by several methods such as decantation and sieving, which are unitary operations and are used to recover solid wastes present in the effluent. If these solid wastes are present in the effluent, then they can cause increased load and require more complex operations (Silva and Naval, 2018). Segregation depended on the constituent material present in the wastes. For different segregation operations, diverse techniques such as sedimentation, sedimentation capacity and density difference sieving and filtration of the material are outstanding. These methods based on principle of particle separation as shown in Table 2.

8.3 Utilization of fish waste as a sustainable organic fertilizer for plant growth

The fish waste is converted into compost from very long time. Composting is an excellent method of recycling organic fish waste into organic fertilizer that can be best used in modern agriculture. This procedure of converting organic waste products into compost will provide an economic and ecological value and benefit for the environment. It enables obtaining a valuable organic fertilizer, which is a substrate of humus and applying it. It is safe and natural process and demolishes disease-causing organisms and flies' larvae. Composting is a cheap method of fish waste disposal as compared to other disposing methods. Fish waste is highly rich in nutrients and organic, inorganic minerals like nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S) and micronutrients such as zinc (Zn), copper (Cu) and manganese (Mn) and Iron (Fe). Thus, fish waste can be used on an industrial scale to convert it into an organic fertilizer. These fertilizers can be applied in agriculture for improving the quality and quantity of agricultural plants yields. This will also help in improving the soil health. Fish waste is rich in nitrogen so it is used for improving the plants growth and it can be converted into a good plant fertilizer (Sumithra and Amala, 2020).

Table 2 Table summarizes various techniques for managing fish waste

Management Technique	Description	Benefits	Estimated Efficiency/Output	Reference
Landfill Disposal	Fish waste is disposed of in permitted landfills	Simple waste removal that does not capitalize on the resource potential of fish waste	0% resource recovery	Dubey et al.(2021)
Land Application	In accordance with solid waste rules, ground fish waste is tilled onto agricultural or silvicultural soil as fertilizer.	Enriches soil and minimizes waste	Up to 20% nutrient recovery	Thirukumaranet al.(2022)
Composting	Using techniques like the indoor method, which entails piling and stirring the trash, fish waste is broken down to produce compost.	Produces valuable compost for agricultural applications	30-50% reduction in waste volume	Isibikaet al.(2021)
Pre-processing	To make waste easier to handle for additional processing, it is chopped or ground.	Makes processing and handling simpler	Increases processing efficiency by 25-30%	Dubey et al.(2021)
Microbial enzyme production	Microbial enzyme production such as lipase, protease, chitinase etc.	hydrosylate quality can be improved in fermentation, enhance the biological activites	Nutritional improvement by 25.35%	Rebah and Miled(2012)
Circular Economy Practices	Focuses on repurposing fish waste to create useful goods including fertilizers, feed for aquaculture, and medications.	Lessens the impact on the environment while generating new fishery revenue streams.	Potentially generates $25 billion by 2030	Rana et al.(2023)

Table 3 Schematic process of bioconversion of fish processing waste (Adapted from Venugopal, 2021)

Class of compounds	Components recovered	Fisheries Resources
Nitrogenous compounds	Protein, gelatin, collagen, protein hydrolysates, bioactive peptides, Proteases, collagenases, chitinases, transglutaminases, β-1,3 Glucanase, β-Galactosidase, catalases, lysozyme, glutathione, peroxidase	Marine food waste and leftover (finfish intestines, shrimp heads), discards from Atlantic seals, cods, salmons, sardine, Red sea bream, Indian mackerel. Octopus, shellfish, squid liver, sea cucumber, tilapia, Arctic, scallop shells, crab shells, marine mussels and other sea organisms and their discards.
Lipids	Rich in polyunsaturated fatty acids, Squalene, Squalamine, Carotenoids, Astaxanthin , B-carotene	Discards of Atlantic cod, seal, salmon, sardine, Indian mackerel, red sea bream.
Elements	Calcium, Phosphopeptides, Hydroxyapatite, Calcium carbonate, Calcium lactate, Calcium acetate	Shellfish, finfish and their remains
Polysaccharide compounds	Hyaluronic acid Glycosaminoglycan Chondroitin Dermatan sulfate, Chitin, Chitosan, Chitosan derivatives, Glucosamine, Oligosaccharides	Abalone, scallop, tilapia, sea cucumber, Arctic scallop shell, crab shell Marine mussel and other organisms

8.7 Modern biotransformation

Microalgae possess a great potential of transforming fish waste into a very rich biomass of bioactive chemicals as well as single-cell protein, significant volumes of effluents of the seafood sector can be handled (Ahmad et al., 2022). Micro algae have properties of high lipid content and they can quickly grow, therefore in future they can be used for producing third generation biofuel (Koyande et al., 2019). Single cell protein oil can be used for generation of good biofuel. Therefore, oleaginous microbe cultivation can be fruitful plan for transforming cheap organic waste for energy production.

9. Conclusion

Wastes generated from the fisheries can be efficiently converted into useful products like health promoting nutrients such as peptides, enzymes, organic fertilizers, biodegradable polymers and other renewable energy forms. Consuming such waste through eco-friendly ways like microbial and enzymatic conversions not only reduces the environmental degradation but also promotes reversible economic growth. In countries like India, the fish processing industries mark their significance largely but the improper waste disposal remains a pressing problem. To overcome such issues, an integrated measure, emphasizing the sustainable waste handling, processing through innovative waste conversion techniques and strict regulatory enforcement is required. Public awareness and industrial solutions can be promising in transforming the fishery waste into valuable resource and also promoting such approaches are key to safeguard the marine biodiversity and ensuring the sustainable livelihood for upcoming generations.

Author contribution

Jyoti Verma, **Anamta Rizvi, Sailendra Kumar, Priyanshu Kumar, Pooja Adwani and Vishwajeet**: Literature review, Conceptualization, Writing and Formal analysis. **Jiwan Singh**: Review, editing and final validation.

Acknowledgement

The authors would like to acknowledge Department of Biotechnology, Babasaheb Bhimrao Ambedkar University for providing essential support. We would like to acknowledge the Department of Science and Technology (DST), Govt. of India for providing the DST-INSPIRE fellowship to Anamta Rizvi; Ministry of Social Justice and Empowerment for providing National Fellowship for OBC (NFOBC) to Sailendra Kumar and CSIR for providing fellowship to Vishwajeet.

Conflict of interest

The authors have disclosed no conflicts of interest.

References

Abelson, A., 2005. Coral recruitment to the reefs of Eilat, Red Sea: temporal and spatial variation, and possible effects of anthropogenic disturbances. Marine Poll. Bulle. 50, 576-582.

Ahmad, A., Hassan, S.W., Banat, F., 2022. An overview of microalgae biomass as a sustainable aquaculture feed ingredient. Food security and circular economy. Bioeng. 13(4), 9521-9547.

Akinnawo, S.O., 2023. Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. Environ. Chall. 12, 100733

Ayilara, M.S., Olanrewaju, O.S., Babalola, O., Odeyemi, O., 2020. Waste management through composting: Challenges and potentials. Sustain. 12 (11), 4456.

Bae, Y., 2024. Regulating Fisheries Subsidies in the WTO. Korea Inter. Law Rev. 67, 39-73.

Bashir, I., Lone F.A., Bhat R.A., Mir S.A., Dar Z.A., Dar S.A., 2020. Concerns and threats of contamination on aquatic ecosystems. Biorem. Biotechnol. 27, 1-26.

Cooke, S.J., Nguyen, V.M., Dettmers, J.M., Arlinghaus, R.O.B.E.R.T., Quist, M.C., Tweddle, D. E.N.I.S., Cowx, I.G., 2016. Sustainable inland fisheries–Perspectives from the recreational, commercial and subsistence sectors from around the globe. Conserv. Biol. 20, 467-505.

Coppola, D., C. Lauritano, F. P. Esposito, G. Riccio, C. Rizzo, D. de Pascale, 2021. Fish Waste: From Problem to Valuable Resource. Mar. Drugs 19 (2), 116.

Dubey, S., Meher, P., Shetty, A., Umtol, A., Kirloskar, S., 2021. Waste Management in Fishery Industry: A Review. Inter. J. Eng. Res. Technol. 9(3), 206-209.

Hlordzi, V., Kuebutornye, F.K., Afriyie, G., Abarike, E.D., Lu, Y., Chi, S., Anokyewaa, M.A., 2020. The use of Bacillus species in maintenance of water quality in aquaculture: A review. Aquac. Reports, 18, 100503.

Ioannis, S.A., Aikaterini, K., 2008. Fish industry waste: treatments, environmental impacts, current and potential uses. Inter. J. Food Sci. Technol., 43(4), 726-745.

Isibika, A., Vinnerås, B., Kibazohi, O., Zurbrügg, C., Lalander, C., 2021. Co-composting of banana peel and orange peel waste with fish waste to improve conversion by black soldier fly (Hermetiaillucens (L.), Diptera: Stratiomyidae) larvae. J. Clean. Prod., 318,128570.

Islam, J., Yap, E.E.S., Krongpong, L., Toppe, J., Peñarubia, O.R., 2021. Fish waste management: Assmt.on potential prod. and utilization of fish silage in Bangladesh, Philippines and Thailand. FAO,Aquac. Fish Circular No. 1216

Jin, M., X. Wang, T. Ren, J. Wang, J. Shan, 2021. Microplastics contamination in food and beverages: Direct exposure to humans. J. Food Sci. 86(7), 2816-2837.

Kapsalis, V.C., Kalavrouziotis, I.K., 2021. Eutrophication-A Worldwide Water Quality Issue. In: Zamparas, M.G., Kyriakopoulos, G.L. (eds) Chemical Lake Restoration. Springer, Cham., 21.

Khairul, U.T., N.I.M. Idris, R.M. Shah, I.H.M. Nawi, N. Che Soh, 2025. Evaluation of Minerals Composition in Fish Bone Meal as Organic Fertilizer Development for Sustainable Environment. Curr. World Environ., 19(3), 1260–1268.

Koyande, A.K., Show, P.L., Guo, R., Tang, B., Ogino, C., 2019. Bio-processing of algal bio-refinery: A review on current advances and future perspectives. Bioeng. 10(1), 574-592.

Kumar, D.J.P., Mishra, R.K., Chinnam, S., Binnal, P., Dwivedi, N., 2024. A comprehensive study on anaerobic digestion of organic solid waste: A review on configurations, operating parameters, techno-economic analysis and current trends vol.5, 33-49.

Kurniasih, S.D., Soesilo T.E.B., Soemantojo, R., 2018. Pollutants of Fish Processing Industry and Assessment of its Waste Management by Wastewater Quality Standards. E3S Web of Conferences 68 (03006).

Kvasnicka, J., K.S. Stylianou, V.K. Nguyen, L. Huang, W.A. Chiu, G.A. Burton, J. Semrau, and O. Jolliet, 2019.

Human health benefits from fish consumption vs. Risks from inhalation exposures associated with contaminated sediment remediation: Dredging of the hudson river. Environ. Health Perspect. 127 (12), 127004.

Lan, J., P. Liu, X. Hu, and S. Zhu, 2024. Harmful Algal Blooms in Eutrophic Marine Environments: Causes, Monitoring, and Treatment. Multidisciplinary Digital Publishing Institute (MDPI). Water 16 (17), 2525.

Marinho-Soriano, E., Azevedo C.A.A., Trigueiro T.G., Pereira D.C., Carneiro M.A.A., Camara, M.R., 2011. Bioremediation of aquaculture wastewater using macroalgae and Artemia. Int. Biodeterior. Biodegrad., 65(1), 253-257.

Mehta, N.K., S. Sharma, H.H. Triphati, K. Satvik, K. Aruna, B. K. Choudhary, D. K. Meena, 2023. Conversion of fish processing waste to value-added commodities: a waste to wealth strategies for greening of the environment. Organic Farming: Global Perspectives and Methods, Second Edition: 421-466.

Mo, W. Y., Man, Y. B., Wong, M.H., 2018. Use of food waste, fish waste and food processing waste for China's aquaculture industry: Needs and challenge. Sci. Total Env., 613, 635-643.

Monteiro, A.,D. Paquincha, F. Martins, R. P. Queirós, J.A. Saraiva, J. Švarc-Gajić, N. Nastić, C. Delerue-Matos, and A. P. Carvalho, 2018. Liquid by-products from fish canning industry as sustainable sources of ω3 lipids. J. of Environ. Manage.13, 219, 1-9.

Musyoka, S., 2016. Concept of microbial bioremediation in aquaculture wastes; Review. Inter. J. Adv. Sci. Tech. Res. 5(6), 1-10.

Nagarajan, R.S. Thirumalaisamy, and E. Lakshumanan, 2012. Impact of leachate on groundwater pollution due to non-engineered municipal solid waste landfill sites of Erode city, Tamil Nadu, India. Iran. J. Environ. Heal. Sci. Eng., 9(1), 35.

Nama, S.A., Shanmughan, B.B., Nayak, S., Bhushan, Ramteke, K., 2023. Impacts of marine debris on coral reef ecosystem: A review for conservation and ecological monitoring of the coral reef ecosystem 189, 114755.

Nelluri, P., Rout, R.K., Tammineni, D.K., Joshi, T.J., Sivaranjani, S., 2024. Technologies for management of fish waste & value addition. Food Humanity 2, 100228.

Nichols, C.R., Zinnert J., Young, D.R., 2019. Degradation of coastal ecosystems: Causes, impacts and mitigation efforts. Complex and Impermanent, Coas. Res. Libr. 27, 119-136.

Oliveira, Lima J.E., Dimitri da Silva, Kuprych, V., Faria, P.M., Teixeira, C.,Ferreira Cruz, E., Miguel Rosado da Cruz, A., 2021.Traceability system for quality monitoring in the fishery and aquaculture value chain. J. Agri. Food Res. 5, 100169.

Ozogul, F., Cagalj, M., Šimat, V., Ozogul, Y., Tkaczewska, J., Hassoun, A., Phadke, G.G., 2021. Recent developments in valorisation of bioactive ingredients in discard/seafood processing by-products. Trends Food Sci. Technol. 116, 559-582.

Rajeswari, C., Padmavathy, P., Aanand, S., 2018. Composting of Fish Waste: A Review. Inter. J. Appl. Res., 4 (6), 242-249.

Rana, Singh, S.A., Surasani, V.K.R., Kapoor, S., Desai, A., and Kumar, S., 2023. Fish processing waste: a novel source of non-conventional functional proteins Int. J. Food Sci. Technol. 58(5), 2637-2644.

Rebah F.B., Miled N., 2012. Fish processing wastes for microbial enzyme production: a review. Biotech. 3(4), 255-265.

Rifath, M.R.A., a Thariq, M.G.M., 2023. Fish Waste to Fish Meal: Potential, Sustainability and Emerging Issues Related to Microplastics and Regulations. J. Fish. Environ. 47(2), 1-18.

Sahana M.D., Balange A.K., Layana, P., Naidu, B.C., 2023. Chapter Five - Harnessing value and sustainability: Fish waste valorization and the production of valuable byproducts.Adv. Food Nutr. Res. 107,175-192.

Saleh, N.E., Wassef, E.A., Abdel-Mohsen, H.H., 2022. Sustainable Fish and Seafood Production and Processing, Editor(s): Charis M. Galanakis, Sustainable Fish Production and Processing, Pages 259-291, Academic Press.

Santana, T.M.F., Dantas D.M., Monteiro Dos Santos D.K., Kojima J.T., Pastrana Y.M., De Jesus R.S., Gonçalves L.U., 2023. Fish Viscera Silage: Production, Characterization, and Digestibility of Nutrients and Energy for Tambaqui Juveniles. Fishes 8(2), 1-11.

Shavandi, A., Hou Y., Carne A., McConnell M., Din A.A.E., Bekhit, 2019. Marine Waste Utilization as a Source of Functional and Health Compounds. Adv. in Food and Nutri. Res., 87, 187-254.

Silva, Y. D. S., & Naval, L. P., 2018. Segregation of solid waste from a fish-processing industry: a sustainable action. Rev. Ambient.Água, *13*(2), e2155.

Sumaila, U.R., Bellmann, C., Tipping, A., 2016. Fishing for the future: An overview of Chall. and opp. Marine Policy, 69, 173-180.

Sumithra, T.G. and Amala, PV., 2020, Fish waste management: turning fish waste into healthy fertilizer. In: Aquaculture Worker. ICAR- Central Marine Fisheries Research Institute, Kochi, pp. 131-140.

Thilsted, S.H., Thorne-Lyman, A., Webb, P., Bogard, J.R., Subasinghe, R., Phillips, M.J., Allison, E. H., 2016. Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. Food Policy, 61, 126-131.

Thirukumaran R., Anupriya V.J., Krishnamoorthy S., Ramakrishnan P., Moses JA., Anandharamakrishnan, C., 2022. Resource recovery from fish waste: Prospects and the usage of intensified extraction technologies. Chemosphere 299, 134361.

Turner, A.M., Chislock M.F., 2010. Blinded by the stink: nutrient enrichment impairs the perception of predation risk by freshwater snails. Ecol. Appl. 20, 2089-2095.

Venugopal, V., 2021.Valorization of Seafood Processing Discards: Bioconversion and Bio-Refinery Approaches. Front. Sustain. Food Syst. 5:611835.

Yamamoto, M., Saleh, F., Ohtsuka, A., Hayashi, K., 2005. New fermentation technique to process fish waste. Anim. Sci. J. 76(3), 245-248.

Zhang, J., Ç. Akyol, E. Meers, 2023. Nutrient recovery and recycling from fishery waste and by-products. J. Environ. Manage. 348, 119266.

Cite this article:
Verma, J., Kumar, P., RizviA., Kumar, S., Adwani, A., Vishwajeet, Singh, J., 2025. Fisheries waste management a novel approach for technology transfer: A review J. Appl. Sci. Innov. Technol. 4 (2), 37-46.