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# Value Added Products Production From Fish Skin, a Review

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**Abstract**
*Modern methods of seafood processing lead to the collection of a large amount of waste materials such as skin, head, tail, shell, scales, backbone, etc. In addition to the environment, improper waste management has negative consequences on human health. Seafood wastes often contain large amounts of bioactive peptides and bio compounds, which show characteristics such as biocompatibility, biodegradability, antimicrobial, antitumor, and antioxidant properties. This review is an attempt to convert marine waste into added value as a solution to waste management. From the data of some published articles from Science Direct, Pub Med, Scopus Springer Link, and Scopus databases, it was done using the keywords of aquatic waste, environmental protection, bioactive peptides, high-added value products, and biological products. The results showed that in Iran, aquatic wastes are used for the laboratory production of collagen, gelatin, sauce, fish meal, chondroitin sulfate, bone powder, chitin, organic fertilizer, chitosan, hydrolyzed protein, isinglass, silage, peptone, and the enzyme. Currently, aquatic wastes are used to produce fish powder, oil, and fish leather. The skin, and viscera are the parts that are most used in the preparation of value-added products. It is suggested that aquatic wastes be used to produce compounds such as compost, biogas, insulin, wound dressing, albumin, flavors, guanine crystals, squalene, methane, fish protein concentrate, pesticides, and fish compost in Iran.*

**Keywords:** High value-added products, Bio-products, Global solutions, Seafood waste, Waste management.

## Introduction

During the last century, the dramatic growth of the world's population and consumer demand led to excessive consumption of resources, which left a great impact on ecosystems and biodiversity. At the same time, improper disposal of production waste and by-products also harms the environment and human health (Zhao et al., 2022; Alawli et al., 2019). Until today, interactions between humans and the environment have been based on a model of linear economy including extraction, processing, production, and disposal of unused products and by-products produced during the processing of the main product as waste to the environment (Ucak et al., 2021; Coppola et al., 2021). This linear economy model is no longer compatible with the current capacities of this planet. Global demand for food is increasing as the population grows, which in turn increases the demand for seafood as part of a healthy diet (Mo et al., 2018; Murthy et al., 2018). Seafood is considered a very broad food group, with different groups having better environmental performance than other protein-rich foods, such as terrestrial animals. The production of these foods is obtained through aquaculture or wild fishing (Mohan et al., 2020). According to the report of the FAO, the global production of seafood (fish, mollusks, crustaceans, and other aquatic animals) reached approximately 178 million t in 2020, of which 25% was wasted. The Food and Agriculture Organization of the United Nations estimates the value of seafood trade at $406 billion and is expected to grow by more than 13 percent in terms of production value in 2030. Also, the increase in seafood consumption in the world from 1961 to 2019 (3%) led to the creation of large amounts of waste, waste accumulation, and environmental pollution (FAO, 2022). The reuse of waste and by-products is considered very important to transform low-value waste into new economic products. Therefore, effective strategies are needed to manage seafood waste and prevent wastage and environmental pollution. Like many other food production systems, seafood must use concepts of life cycle thinking and economics to increase production efficiency and reduce its environmental impact, which is possible through valorization strategies or nutrient recovery technologies (Commission of European Union, 2020). Valorizing waste to produce value-added products that facilitate the recycling of resources and energy, and the full use of seafood waste to produce renewable and biodegradable biopolymers prepared from seafood waste, bioactive and beneficial compounds for use in the food industry is a vital method for the sustainable use of resources, increasing resource efficiency, and reducing environmental concerns, which is an important food source for the human food program, and fulfills the objectives of the economic cycle. Therefore, creating a sustainable food resource production system through effective recycling of waste and its reduction helps to protect the environment (Nawaz et al., 2020; Shahidi et al., 2019).

The waste economy cycle was launched by the European Union as part of the European Green Deal. Reversing value chains and processes will help support greater use of renewable energy, responsible use of resources, and reuse and valorization of by-products and residues generated from the seafood processing industry. To avoid wasting seafood nutrients, energy, and elements along the supply chain, identifying the value of these ingredients is considered mandatory. The next step is to design and implement new schemes for valorizing and exploiting seafood by-products, as well as promoting more environmentally, socially, and economically sustainable business models. Underutilization of by-products is considered a wasted opportunity (Commission of European Union, 2020).

The by-products and residues of fish processing including skin, head, intestines, bones, scales, and fins are the source of several potentially valuable molecules such as proteins, peptides, lipids, vitamins, minerals, pigments, and enzymes. In addition, crustacean wastes contain chitin and chitosan, which are valuable for the production of high added value and economically attractive products. In this regard, in Iran, the production of compounds with high added value such as sauce, bone powder, collagen, gelatin, enzyme, peptone, hydrolyzed protein, silage, chitin, chitosan, leather, astaxanthin, and oil from waste products was investigated by several researchers (Cooney et al., 2023; Kandyliari et al., 2020).

This review focuses on the by-products obtained from the processing of seafood into consumable products, the identification of opportunities for waste to enter the economy cycle in the seafood production chain, emerging strategies and opportunities for the economy cycle, reuse of waste as Inexpensive raw material for the production of biodegradable and high value-added materials, focuses on reducing waste disposal, by-products, pressure on natural resources and environmental pollution, and current methods for waste management, It also introduces future opportunities for the valorization of seafood by-products.

## Methods

The present research was conducted by reviewing published studies on aquatic waste from Iran. The data of some published articles from databases including Science Direct, Pub Med, Web of Science, Google Scholar, Springer, and Scopus were used regarding the products prepared from aquatic waste. Search using keywords aquatic waste, seafood nutrient recycling, economic turnaround, seafood waste management, fishery waste, environmental protection, bioactive peptides, value-added products, biological products, leather, pigment, collagen, and gelatin. , sauce, fish meal, bone meal, hydrolyzed protein, peptone, enzyme, and aquatic processing were done. The present review was conducted by searching for peer-reviewed studies related to seafood processing waste, by-product valuation, and the turning of the economy. Amount of waste calculated on Iranian Fisheries Organization (2023).

## Results

As can be seen in Table 1, the head, and viscera have the largest part of the waste, and after that, the bone, trimmings, and skin are placed in the second, third, and fourth positions, respectively.

In Iran, the total wild catch and aquaculture during the years 2016 - 2021 was estimated at 1258460-1093719 t. 437488 - 503384 t of waste were produced during these years, including 40% of the catch. Therefore, was produced a large amount of waste (Table 1).

**Table 1:** Byproducts from aquatic processing according to Iranian Fisheries Organization (2023)

| **By products** | **Trimming** | **Bone** | **Skin** | **Viscera** | **Head** |
|---|---|---|---|---|---|
| The ratio of the weight of products to the weight of fish (%) | 1-5 | 10 -16 | 1-3 | 15-20 | 14-20 |
| In Iran | | | | | |
| **By products** | **Trimming** | **Bone** | **Skin** | **Viscera** | **Head** |
| The ratio of the weight of products to the weight of fish (t) | 21874-25169 | 69998-80542 | 13125-15102 | 87498-100677 | 87498-100677 |

Different lowercase letters in a column indicate statistically significant differences ($P<0.05$).

According to Table 2, in Iran, wastes of shrimp, white fish, Alosa caspia,, squid, sardine, schizothrax, tuna, farmed carp, rainbow trout, king koli, Caspian sea bream, kilka, crucian carp, and sturgeon are used to preparing of high-value products. So far, sauce, culture medium, collagen, gelatin, chitin, chitosan, hydrolyzed protein, bone meal, fish meal, silage, peptone, isinglass, leather, astaxanthin, biofuel, protozoan protein, organic fertilizer, oil and enzyme from aquatic wastes are produced in Iran (experimentally). Except for leather, powder, and oil other products are not mass-produced commercially. So that it can be seen that most of the studies have been done on the residues on the skin and viscera, and these organs have the greatest potential to produce value-added products. Studies for the production of enzyme, hydrolyzed protein, and sauce on intestines and viscera, while studies for the production of gelatin, collagen, sauce and hydrolyzed protein have been conducted on the skin. Bone has been used to produce powder, chitin, and chitosan. The head also has the potential to be used to produce sauce, hydrolyzed protein, gelatin, and collagen. Products including hydrolyzed protein, isinglass, leather, sauce, and gelatin have been produced from sturgeon waste.

In Iran, most of the studies have been done for hydrolyzed protein and enzyme production. No published reports were found regarding the production of insulin, albumin, methane, flavors, biogas, guanine crystals, squalene, fish protein concentrate, pesticides, antimicrobial peptide, wound dressing, and fish compost in Iran.

**Table 2:** Biological and food products prepared from aquatic waste in Iran

| Product | Aquatic species | References |
|---|---|---|
| Sauce | Sturgeon, shrimp | Seifzadeh, 2022 |
| Hydrolyzed protein | Siberian sturgeon (*Acipenser baerii*) | Khodayi et al., 2018; |
| Gelatin | Sturgeon | Kochakian Sabour, 2014; Kouchakian Sabour et al., 2001 |
| Leather | Siberian sturgeon | Kordjazi et al., 2018 |
| Astaxanthin | Western white leg shrimp | Saber Baghban et al., 2022 |
| Organic fertilizer | Fish and shrimp | Shahsavani et al., 2017; Salehi and Safaei, 2017 |
| Collagen | Farmed carp | Jalili et al., 2021; Seifzadeh, 2022 |
| Silage | Rainbow trout, Anchovy Kilka | Raziye et al., 2023; Safari et al., 2021; Khudanazari et al., 2019 |
| Oil | Rainbow trout, Tuna fish (*Thunnus tonggol, Katsuwonus pelamis, Thunnus Albacares*) | Seydanloo et al., 2022; Hosseini and Eskandari, 2022; Vardizadeh et al., 2021; Taati Keli et al., 2018 |
| Biodiesel | Fish | Yahyaee et al., 2013 |

Today, the increasing exploitation of aquatic resources and their optimal and comprehensive use to reduce waste and produce by-products is of particular importance. A by-product refers to something that is not considered a salable product but can be used after purification. The term waste refers to products that cannot be used for feed or food but must be composted or disposed of. The European Union Regulation (EC No.1774/2002) defines animal by-products as parts of the animal that are not suitable for human consumption. Although co-products, co-streams, fish offal, fish viscera, discards, or waste are used synonymously to describe the non-edible parts of the seafood processing industry, the term waste seems to mean it has no value. Stevens et al. (2018) defined the term by-products as edible or non-edible materials that remain after the preparation of the main products. The main by-products of aquatic processing industries include intestines and viscera, skin, scales, vertebral column, and trunk bones. Of course, trimming and blood can also be mentioned. Table 1 shows that the largest part of the waste is made up of the head.

In Iran, aquaculture production increased from 459521 tons in 2016 to 556000 t in 2021. Considering that on average 40% of aquaculture products are waste, during these years, 222400-183808 tons of waste were produced (Iranian Fisheries Organization [IFO], 2023). Therefore, this huge potential resource can be considered as a valuable raw material for the production of other products in the future. In Iran, aquaculture is one of the developing activities that has grown significantly in recent years and has succeeded in providing food and playing a role in the country's economy. One of the important measures that can boost the country's fishing economy is the use of waste and the use of by-products and fish by-products. For seafood, there are large amounts of by-products generated through processing that are lost in various ways. But they can be valued for the production of feed, value-added products, and food production. The challenge of seafood loss due to climate change and emerging recycling strategies should also be considered and integrated into the valuation pathway. This framework can enable producers and investors to adapt to the economic cycle by considering the economic viability of products obtained from waste. Communication, education, and engagement with stakeholders are key to transitioning to the economic cycle. Increasing awareness creates motivation and demand for the exploitation of seafood by-products.

By using traditional methods, during the last few decades, fish wastes such as kilka, sardine, and tuna have been turned into powder and used in feeding livestock, poultry, and aquatic animals. Global aquaculture demand for fishmeal was 2.09 million tons in 1999 and will increase to 10.4 million tons by 2030 (FAO, 2022). However, the production of new products from waste in a modern way is expanding, and as can be seen in Table 2, studies on aquatic wastes for the production of leather, collagen, gelatin, silage, sauce, hydrolyzed protein, and oil are being developed.

The skin can be used to produce collagen, gelatin, sauces, oils, astaxanthin, leather, fishing bait, protein, peptides, minerals, and flavorings. However, according to Table 2, it has not been used in Iran for the production of minerals, fishing bait, and flavoring compounds.

Fish waste is a huge and cheap source of collagen and is considered the main source of aquatic collagen for biotechnology applications. 30% of the solid waste consists of bones and skin, which, due to its rich content of collagen, makes fish waste a favorable source for collagen extraction with a recovery rate of 36-54% (Blanco et al., 2019). Fish skin contains type 1 collagen with a high degree of purity (about 70%) according to age, species, and fishing season. It has been proven that collagen has a great capacity to retain skin water and has no potential to irritate human skin (Coppola et al., 2020). Although, collagen peptides derived from fish skin have a higher price compared to other types of collagen. But they are significantly more useful and show higher absorption. This type of collagen is composed of smaller peptides (smaller protein pieces) than other collagens, and due to its low molecular weight, it is 1.5-5 times easier to digest, absorb, and distribute in the body than other types (Seifzadeh, 2023a). Fish collagen is different from other collagens due to having a large amount of lysine, glycine, proline, and hydroxyproline amino acids. Together, these nutritional compounds stimulate skin cells, joints, and bones to produce proteins, including collagen, and help build body tissues (Elbialy et al., 2020). Lysine not only plays an essential role in the production of this protein but also strengthens the body's immune function. Utilization of aquatic by-products as a new source of collagen due to water solubility, safety, low immunogenicity, reproducibility of its effects, easy extraction, high collagen content, biocompatibility, free from the risks of animal diseases and pathogens, compatibility with the environment, content Insignificance of biological pollutants and toxins, religious restrictions and lack of moral significance, minor problems of monitoring and quality control attracted increasing attention (Ge et al., 2020). The use of collagen in treatment dates back to the 1970s. Traditionally, collagen has been used as a biopolymer for dressings, tissue engineering, regenerative medicine, dentistry (pulling teeth and implants), grafting, periodontal therapy, corneal fillers, orthopedics, and surgery to make synthetic skin substitutes and treat burns (Ibrahim et al., 2020). Due to its high tensile strength, collagen is used in pharmaceuticals and prolotherapy to strengthen loose ligaments. Hemocoagulant cotton textiles, injections for soft tissue abscess treatment, dental bone fillers; and making a permeable membrane to regenerate the soft tissue around the gums are examples of the use of collagen in treatment (Jafari et al., 2020). Collagen has been used as a barrier to prevent epithelial migration and provide a way for cells with the ability to regenerate in the damaged area, collagen-based membranes. Subcutaneous injection of collagen leads to improvement of quality, and density of skin, and repair of skin defects (Seifzadeh, 2023a). Collagen fillers are used to reverse the signs of aging. Collagen is the main component of several hydrogels that can be used as beauty masks (Lim et al., 2019). These types of cosmetics may restore the elasticity of the skin. Many polymers of natural origin can also play an important role in cosmetic formulations and act as thickening agents (Seifzadeh, 2023a).

In Iran, shrimp farming fluctuated between 8620 - 12174 t during 2016 - 2021. Considering that the shrimp industry produces a large amount of solid waste, which is approximately 45-55% of the weight of raw shrimp, it led to the production of 3879-5478.3 tons of shrimp waste in the country (Iranian Fisheries Organization [IFO], 2023). Shrimp waste is a rich source of protein (32.06% of dry weight), which can be a suitable protein substitute for part of society's needs. In addition, it consists of fat and several minerals such as calcium, iron, magnesium, sodium, etc., which can be a potential source for exploitation for human consumption (Seifzadeh, 2022). Shrimp waste sauce is a traditional fermented product by salt containing carbohydrates, protein soluble in salt in the form of amino acids and peptides, transparent, light yellow or brown, with a pungent smell, salty or salty taste, rich in essential fatty acids and amounts Significant is eicosapentaenoic acid and docosahexaenoic acid, which are usually used to improve the smell and taste of food. Currently, the sauce is traditionally produced from fish, but the sauce was produced from shrimp waste only as an experiment.

Gelatin is a protein, colloid, and the oldest macromolecule that is obtained from the hydrolysis of collagen found in the skin, bone, and connective tissue of animals, including aquatic animals (Qiu et al., 2019). Gelatin in the food industry to reduce calories in food to increase the level of protein, especially in the food of athletes and bodybuilders, as well as to reduce carbohydrates in formulated foods for diabetic patients, as a clarifying agent in drinks and juices, in the preparation of marmalade, jelly, sweets, ice cream, etc. are used, which is easily absorbed in the body and helps the digestion of other foods by forming an emulsion with fats and proteins. Global demand for fish gelatin has increased in recent years (IFRO, 2013). Recent reports show that the annual extraction of gelatin is approximately 326 thousand tons, of which 46% is from pig skin, 4.29% from cow and sheep skin, 1.23% from bones, and 1.5% from other production sources (IFRO, 2014a). The yield of extracting gelatin from fish is less than gelatin extracted from mammals and is approximately 6-19%. Although gelatin consumed in the world has wide and various uses, there are serious warnings against the consumption of gelatin (Koochakian, 2001). This is mainly due to the transmission of pathogens and religious tendencies (Islam, Judaism, and Hinduism) as well as the strong adherence to vegetarianism throughout the world. In addition to the mentioned cases, to use fish gelatin instead of mammal gelatin, we can especially mention its quality such as lower melting point and fast melting in the mouth without any chewing residue, which doubles the advantage of using it. Although gelatin has been studied since 1950 AD, studies on the extraction of gelatin from fish have been started in recent years, so fish gelatin in the initial stage of the year includes about one percent of the total production of gelatin in the world (Jalili & Seyfzadeh, 2022).

Leather is another product that can be made from fish waste (skin). The production of leather from aquatic animals is one of their important and secondary products, which has a long history in the world, and the production of fish leather has also started in Iran and is progressing rapidly. Fish leather is included in the light leather group and besides being thin, it has high elasticity. The advantages of fish leather include resistance to water due to being rich in oil, very strong and durable, resistant to cold and tolerating temperatures of -10 to -20 oC, flexibility, beautiful and bright colors, and its layered surface, compatibility with the environment, reduction of atmospheric and water pollution, use of minimal chemicals for tanning and dyeing, lower price, high dyeability, availability of resources, and high sustainability. At present, cows and sheep are used to prepare leather, which is usually brittle and breaks due to cold. Common leathers such as snake and varan skin are very expensive and their resources are highly endangered. But fish leather does not have such conditions, from the types of fish that are used to produce leather, we can refer to salmon, loti, wolf fish, oil fish, sturgeon, eel, tilapia, bite fish, and shark. In some countries such as Kenya, fish leather has brought a lot of income to producers. In Iran, fish leather work, including sturgeon; Carp, tilapia, and salmon has been carried out on a small scale and research level, but there is a large platform for their production. Today, several exclusive factories producing fish leather have been set up in the world, such as the Republic of Ingush, Russia, which uses the skin of various fish to produce leather.

Shrimp waste, including shrimp skin, is rich in micronutrients, which are more valuable than shrimp meat. Various compounds such as pigment can be prepared from shrimp skin. There are pigments in shrimp skin called astaxanthin. This pigment is anti-cancer and a very strong antioxidant, which is prepared from the skins of shrimp.

The alarming rate of population growth has increased the demand for food production in third-world countries and has led to a large gap between demand and supply. This situation has led to an increase in the demand for the formulation of alternative protein food sources. Since human nutrition is currently based on fisheries, which accounts for 50% of fish production for human consumption, and significant amounts of intestines and viscera are obtained during processing, they can be used for production (Spalvins et al. 2018; Safari & Yaqoubzadeh, 2013).

According to Table 2, the production of hydrolyzed proteins from viscera has attracted the attention of many researchers. Alosa caspia, rainbow trout, sardine, schizothrax, common kilka, yellowfin tuna, rainbow trout, farmed Siberian carp and silver carp are among the aquatic species from which the preparation of hydrolyzed protein was successful. Hydrolyzed proteins are compounds with low molecular weight, which are easily absorbed after entering the body and play important biological roles. These bioactive compounds are rich in chondroitin sulfate and one of their most important functions can be mentioned as anti-oxidation, anti-microbial, and anti-cancer properties and increasing the body's immune system (Mousakhani Ganjeh et al., 2023; Abuine et al., 2019; Li et al., 2017; Khajovi et al., 2015). Their antioxidant ability is attributed to their ability to remove free radicals, chelate metals, remove oxygen or give hydrogen, and prevent the penetration of fat oxidation initiators. On the other hand, due to the shortness of the peptide chain, they have high digestibility and can be used as a protein supplement in human, animal, and aquatic nutrition (Vázquez et al., 2020; Araujo et al., 2021; Chaklader et al., 2023; Desai et al., 2022). Also, the effective role of hydrolyzed proteins as a nitrogen source in bacterial culture environments has been proven. Flavor enhancers in sweets, stabilizers of drinks, substitutes for milk in the ration of calves, improvement of water binding in meat products, and reduction of bleeding from raw meat are other features of the fish hydrolyzed protein (Ranasinghe et al., 2021; Laishram et al., 2023; Petrova et al., 2018; Granito et al., 2018).

As shown in Table 2, silage can be obtained from all parts of aquatic wastes such as head, tail, skin, intestines and entrails, and fins. It can also be prepared from fish powder, but its production has been investigated only from rainbow trout and common kilka. Silage is one of the fermentation products based on autolysis, chemical or microbial reactions. This product has various applications and can be used in agricultural industries as a biological fertilizer and in the diet of livestock, poultry, and aquatic animals as an alternative source of protein. The nutritional value of silage varies depending on the type of raw material, the type of process used, and the reduction of moisture in the product (Khudanazari et al., 2019; Spalvins et al., 2018).

Paying attention to Table 2 shows that organic fertilizer is prepared from organs such as skin, head, neck, and internal and aquatic organs including fish and shrimp. Indiscriminate use of chemical fertilizers caused the organic matter of agricultural land to decrease and the composition of the soil to become hard and undesirable. Replacing them with organic fertilizers plays an important role in the health of the environment. Organic materials are known as one of the pillars of plant nutrition and soil fertility due to the effects they have on the physical and biological properties of soil. Organic fertilizers are the most important factor in providing organic matter in the plant rhizosphere (Radziemska et al., 2019). In addition to the nutritional role, these fertilizers have a significant effect in improving the quality of products, and physical properties and increasing the biological activity of the soil. Although the use of inorganic chemical fertilizers is the fastest way to provide the nutrients needed by plants, the high costs of using chemical fertilizers, causing pollution, and destroying the environment and soil, are worrying (Illera-Vives et al., 2017). Meanwhile, the development of the use of renewable livestock resources instead of chemical resources can play an important role in fertility and maintaining biological activities, soil organic matter, the health of the agricultural ecosystem, and increasing the quality of crops (López-Mosquera et al., 2011). Fish manure is one of the organic fertilizers that has been used since long ago by groups and individuals who lived near rivers or seas (such as ancient Egyptians and Indians). This fertilizer is rich in nutrients, especially nitrogen and phosphorus, and it is very useful and efficient to overcome the deficiency of these two elements in gardens and fields (Ahuja et al., 2020).

Fish oil plays an important role in many biological processes of the human body. Lack of fish oil in human nutrition due to the presence of polyunsaturated fatty acids causes diseases caused by lack of fish oil such as cardiovascular, high blood pressure, autoimmunity, depression, and some neurological disorders (Monsiváis-Alonso et al., 2020). In humans, eicosahedronoic acid and docosapentanoic acid can be synthesized from alpha-linoleic acid, but this process is not sufficient and only 2-3% of alpha-linoleic acid is converted into eicosahexanoic acid and docosapentanoic acid. During the embryonic period and in the early years of a child's life, docosapentanoic acid is necessary for the formation of the brain and visual system (Alfio et al., 2021). Docosapentanoic acid and arachidonic acid accumulate rapidly in the human brain before and after birth. Today, the sources of eicosahexanoic acid and docosapentanoic acid for human consumption are mainly obtained from fatty fish such as sardines, anchovies, mackerel, menhaden, and tuna, it should be noted that more than 157 million t (89% of the total production) are directly consumed by humans, and the rest is used to produce fish oil and powder (Bonilla-Méndez & Hoyos-Concha, 2018). The global production of fish oil and Europe is about 900,000-800,000 and 190,000 t per year respectively; while no statistics have been reported about the production of fish oil in Iran, The main sources of fish oil production include pelagic species such as salmon, tuna, anchovy, herring and capelin, which have fatty meat. But in Iran, fish oil is produced only from Kilka fish and tuna fish, which is not suitable for human consumption, and fish oil for human consumption is in the group of imported products to the country (Inguglia et al., 2020). Most fish oil consumption is concentrated in aquaculture (73%), while direct human consumption (19%), industry and pharmaceuticals (5%), and other uses (4%) account for it (Kuvendziev et al., 2017). Fish oil constitutes about 2% of the global consumption of fats and oils. Considering the nutritional value of fish oil and the fact that aquatic wastes are rich in oil, it is possible to plan in this field (Debbarma et al., 2023).

Biodiesel production, composting, and biogas are different methods of using fish waste for energy production in the world. Currently, the use of renewable energy, especially biofuels, has received a lot of attention in the world. From renewable energy sources, the potential of biofuel production in Iran is very high, and only biodiesel from fish waste has been produced in the laboratory. The increasing demand for fossil fuels in the world, the reduction of fossil fuel resources, and pollution problems are among the reasons for the tendency towards alternative renewable sources (Anu Prasanna et al., 2023; Ching-Velasquez et al., 2020; Karkal et al., 2020; Thamarai Kannan et al., 2020; Prakash et al., 2019; Choe et al., 2019). In addition, studies conducted by Wu and Song (2021), Lauritano et al. (2020), Ali et al. (2020), Valente et al. (2021), Ashraf et al. (2020), Atef et al. (2017), Cerda et al. (2018), Seo et al. (2014), Prokopov et al. (2018) and Han et al. (2014) showed that they have produced methane, medicinal products, bioactive peptides, anticancer antimicrobial peptide and compost. However, in Iran, aquatic wastes have not been used to produce these products.

Waste management and its use for food preparation are a big challenge for the economic use of products from the aquatic processing industry. The use of waste as a raw material for the preparation of added value products is economically viable and leads to the recycling of waste and the sustainability of the fishery industry, and helps significantly to prevent the loss of resources and reduce environmental problems. In addition, the introduction of waste into the production cycle leads to higher production efficiency, reducing the demand for natural resources and producing more seafood. But in Iran, waste recycling is limited to the production of leather, oil, and fish meal. The production of products such as collagen, gelatin, hydrolyzed protein, silage, fertilizer, bone powder, chitin, chitosan, sauce, biofuel, astaxanthin, peptone, and enzymes have been done in the laboratory. By-products such as trimmings, which have great potential for protein, peptide, and lipid production, and blood, which are used for fibrin, thrombin, lipid, peptide, and protein production, have not been exploited so far. In addition, the production of insulin, albumin, flavors, biogas, guanine crystals, methane, squalene, fish protein concentrate, wound dressing, pesticides, and compost from aquatic wastes is suggested.

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