

FISH PROCESSING WASTES: POTENTIAL SOURCE OF BYPRODUCTS

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Abstract: The fish processing industry is one of the major business sectors in coastal countries. During the processing of fish or shellfish leads to enormous amounts of waste. The problem of fishery wastes has increased in recent years, becoming a global concern, which is affected by several biological, technical and operational factors as well as socio-economic drivers. Nowadays, both minimize the environmental impact of fish industry waste and recycling of these wastes as a functional byproduct are a very important topic adopted by the experts. Fish processing generates solid wastes that can be as high as 50 to 80% of the original raw material and these wastes are an excellent raw material for the preparation of high value byproducts. In the literature, attempts have been made to study the development of various byproducts from fish and shellfish waste that can be used to produce fish protein concentrate, amino acids, fish oils, minerals, bioactive peptides, collagen, and gelatin as well as other value-added products. These wastes are used in many applications among which the most important are animal feed, biodiesel/biogas, dietetic products, natural pigments, food-packaging applications, cosmetics, enzyme isolation, etc. The main target of this review is to summarize the current and potential uses of fish waste in terms of economic and innovative.

Keywords: fish processing waste, high value byproduct, economic impact, innovation.

Introduction

Nowadays, food production has become a major concern of world people in terms of population growth, urbanization, and climate change. In the future, it may have a deeper impact compared to today. Actually, our food generally originates from agriculture, animal husbandry, and fisheries that have become increasingly market-driven worldwide the present (Chandrasekaran, 2012). Fisheries is a rather ancient human activity and has played an important role in many human societies (Ferraro et al., 2010). Globally, more than 170 million metric tons of fish (including capture and aquaculture), shellfish and others are produced each year (FAO, 2018). There is only about 50-60% of this figure is presented for actual human consumption even if an integrated and sustainable exploitation of fisheries resources (Ferraro et al., 2010). Fisheries worldwide annual discards are estimated to be 25% of the catch (Rustad, 2007) and include “non-target” species, and processing waste and byproducts (Rustad, 2003). Therefore, the overexploitation of fish resources is the main problem. Especially, during the processing of fish or shellfish leads to enormous amounts of wastes. A significant proportion of these wastes is exploited (valorized) to some extent, for example as a substrate for animal feed, fishmeal, and silage. However, the rest that is large quantities of material are disposed. For example, those discards represent a total of 5.2 million tons per year only in the EU (AWARENET, 2004; Ferraro et al., 2010; Mahro & Timm, 2007). A total 3.17 million tons per year (50–75% of the fish) of solid waste and by-products from fillets, salted and smoked fish, a 1.5 million tons per year (30–65% of the fish) from canned fish and 0.5 million tons per year (20– 50%) from processed bivalves (AWARENET, 2004; Ferraro et al., 2010).

The problem of fishery wastes has increased in recent years, becoming a global concern, which is affected by several biological, technical, and operational factors as well as socio-economic drivers (Arvanitoyannis & Kassaveti, 2008). Nowadays, both minimize the environmental impact of fish industry wastes and recycling of these wastes as a functional byproduct are a very important topic adopted by the experts (Arvanitoyannis & Kassaveti, 2008; Bechtel, 2003; Caruso, 2015;

Chandrasekaran, 2012; Espósito et al., 2009; Falch, Rustad, & Aursand, 2006; Fouda, 2018; Ghaly, Ramakrishnan, Brooks, Budge, & Dave, 2013; Healy, Green, & Healy, 2003; Heu, Kim, & Shahidi, 2003; S.-K. Kim & Mendis, 2006; S. K. Kim, 2013; Koli, Sharangdher, Patange, Metar, & Jain, 2015; Koutinas et al., 2014; Liu, Li, & Guo, 2008; Penven, Pérez-Gálvez, & Bergé, 2013; F. Shahidi, 2006; Sierra Lopera, Sepúlveda Rincón, Vásquez Mazo, Figueroa Moreno, & Zapata Montoya, 2018; Torres-León et al., 2018; Wasswa, Tang, & Gu, 2007). All of these experts argue fishery wastes are an excellent raw material for the preparation of high value byproducts.

In the literature, attempts have been made to study the development of various byproducts from fish and shellfish waste that can be used to produce fish protein concentrate, protein, fish oils, peptides, collagen, and gelatin as well as other high value products (Ghaly et al., 2013; S. K. Kim, 2013). These byproducts are used in many applications among which the most important are animal feed, biodiesel/biogas, dietetic products, natural pigments, food-packaging applications, cosmetics, enzyme isolation, etc. The main target of this review is to summarize the current and potential uses of fish waste in terms of economic and innovative.

High value components from marine by-products and waste

Fish Protein and Oil

Fish protein contains a well-balanced amino acid composition that is composed of 16-18 amino acids based upon the species type and seasonal variations (Ghaly et al., 2013). Due to the rich amino acid content of fish, it is being utilized as fishmeal, fish sauce, and fish silage (Abdul-Hamid, Bakar, & Bee, 2002; Arik Çolakoğlu & Künili, 2016; Ghaly et al., 2013).

Fish meal is one of the main products, which are obtained from fish waste, by-catch and other abundant species (Blanco, Sotelo, Chapela, & Pérez-Martín, 2007; Hevrøy, Sandnes, & Hemre, 2004). Fishmeal has excellent nutritional properties, with a high content of digestible protein with balanced essential amino acids and contain other nutrients such as fatty acids, minerals, and vitamins. It is mostly used as a source of protein in feed production in aquaculture, as well as in poultry and cattle breeding (Tacon & Metian, 2008). Fishmeal can exhibit very diverse specifications, in terms of amino acid profile, digestibility, and palatability, depending on the raw material and production process employed (Blanco et al., 2007; Ferraro et al., 2010). Fishmeal from pelagic fish is the most widely used, and may generate an income up to 108 Euro/ton depending on its specific composition; currently, its average market value is 46 Euro/ton (AWARENET, 2004; Ferraro et al., 2010)

Fish sauces are fermented fish products and produced from small pelagic fish or by-products using salt fermentation (Ghaly et al., 2013). It is widely consumed not only in South East Asian countries but also all over the world. Fish sauces are used as an important animal protein supplement for humans.

Fish silage is an excellent protein source having high biological properties for animal feeding (Ghaly et al., 2013). It is a liquid product resulting from the liquefaction of a whole fish or a part (Arvanitoyannis & Kassaveti, 2008; Ghaly et al., 2013)

Fish processing by-products contain fish oil its amount generally depends upon the fat content of the specific fish species. Fish oil is an excellent source of energy that contains highly unsaturated fatty acids and in particular essential fatty acids. Especially, two main fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are polyunsaturated fatty acids and are classified as omega-3 fatty acids. They are mainly found in marine animals that have high polyunsaturated fatty acid content (Ghaly et al., 2013). Omega-3 fatty acid concentrates remain a topic of general interest for the pharmaceutical and food industries, for the production of drugs with enhanced performance and for the production of nutritional supplements (Ferraro et al., 2010; S. K. Kim, 2013). In addition, fish oil contains vitamins and essential minerals such as calcium, phosphorus, magnesium and trace elements. Almost 50% of the bodyweight generated as waste during the fish processing would be a great potential source for good quality fish oil which can be used for human consumption or production of biodiesel (Arvanitoyannis & Kassaveti, 2008; Ghaly et al., 2013). Table 1 shows the content and mean market values of high value components obtained from marine by-products.

Table 1. Content and typical market value of high value components obtained from marine by-products (Ferraro et al., 2010)

High value components	Marine by-products	Content (% w/w)	Market value (Euro/kg)
Polyunsaturated fatty acids (ω -3 and ω -6)	Algae, cod liver, oil of mackerel flesh residues	50–80% in cod liver, 23% are ω -3 PUFA	24 (as purified cod liver oil)
Free amino acids	Mussels, fresh clams, white fish flesh residues, crustacean shells	0.8–2% of taurine, 2.7% of creatine (on dry matter)	n.a.
Chitin and chitosan	Shrimp and crab shells	15–40%	15–750
Collagen and gelatin	Pelagic fish skin, scales and bones	Up to 80% in skin, up to 50% in scales	9–14
Hydroxyapatite	Pelagic fish scales and bones	60–70% in bones, up to 50% in scales	n.a.
Antifreeze proteins	Cold water pelagic fish blood and skin	5–35 mg/ml in cold water fish blood	5000
Astaxanthin	Algae, crustacean shells	2.3–33%	3000–12,000
Enzymes	Algae, pelagic fish viscera	–	14,400 (cod proteases)

Chitin and chitosan

Chitin is the second most important natural polymer in the world after cellulose. It is a structural component of crustaceans such as crabs and shrimps. The crustaceans contain 15–20% chitin by dry weight (Ferraro et al., 2010). Chitosan is commercially obtained mainly from chitin by the deacetylation process performed by the addition of alkali solutions. Chitin and chitosan are ubiquitous marine polysaccharides; over the years, they have attracted a great deal of attention in food, pharmaceutical and health applications due to their distinctive biological and physicochemical characteristics (Ferraro et al., 2010; Kurita, 2006; Fereidoon Shahidi, Arachchi, & Jeon, 1999). The adhesive nature of chitin and chitosan, together with their antioxidant and antimicrobial properties, is a very important property associated with medicine and pharmacology and in food industry in food additives and packaging materials. Different derivatives of chitin and chitosan have been prepared for this purpose in the form of hydrogels, fibers, membranes, scaffolds, and sponges (S. K. Kim, 2013). Shrimp exhibits a higher amount of chitin (30–40%) followed by crab (15–30%) (Table 1).

Collagen and Gelatin

Collagen is the major structural protein found in skins and bones of all animals where it accounts for 30% of the total protein content (Arık Çolakoğlu & Künili, 2016; Ferraro et al., 2010). Food and pharmaceutical industries all over the world are witnessing an increasing demand for collagen and gelatin. Mammalian gelatins (porcine and bovine) are the most popular and widely used. However, fish gelatin reportedly possesses similar characteristics to porcine gelatin, and may, thus, be considered as an alternative to mammalian gelatin for use in food products (S. K. Kim, 2013). Gelatin is a fibrous protein that extracted from collagen and is widely used in many industrial fields, such as food, material, pharmacy, and photography, especially in the food and pharmaceutical industries for its unique chemical and physical properties (Jamilah & Harvinder, 2002; Liu et al., 2008).

Hydroxyapatite

Hydroxyapatite is a naturally occurring mineral of biological and agricultural importance. Human and animal bones and teeth are composed of hydroxyapatite. Research in the biomedical area

has been focusing on the identification of biomaterials with long term physiological compatibility, so current development of advanced materials with biomimetic features is one of the most promising trends in biotechnology (Ferraro et al., 2010). Calcium phosphate is naturally occurring hydroxyapatite. It has highly desirable physicochemical attributes of stability, inertness, and biocompatibility. Calcium phosphate-based compounds are used in several technological applications as biomaterials, in particular, to fabricate bone implants, bone cement, and dental paste.

Antifreeze proteins

Antifreeze proteins are biological antifreeze materials originally found in polar fish. They are also known as thermal hysteresis proteins, which are ice-structuring proteins able to influence the growth of ice crystals and inhibit ice recrystallization (Ferraro et al., 2010). These properties have been utilized in the preservation of biological samples at low temperatures (H. J. Kim et al., 2017). Antifreeze proteins find large applications in frozen food technology, low-fat content food manufacture, transplanted organ cryopreservation, cryosurgery, and aquaculture (Feeney & Yeh, 1998; Venketesh & Dayananda, 2008). Ice-cream manufacturing and frozen meat technology are very important for using antifreeze proteins (Ferraro et al., 2010) that may improve quality in terms of allowing for the maintenance of their natural texture, reduction of cellular damage and loss of nutrients, all of which contributes to preserve their nutritional value (Ferraro et al., 2010; H. J. Kim et al., 2017).

Astaxanthin

Astaxanthin is a reddish pigment that belongs to a group of chemicals called carotenoids. It occurs naturally in certain algae and causes the pink or red color in salmon, trout, lobster, shrimp, and other seafood. In food, it is used as a coloring for salmon, crabs, shrimp, chicken, and egg production. Natural sources of astaxanthin are increasingly being marketed as a functional food ingredient in many countries with high prices (AWARENET, 2004; Ferraro et al., 2010) and fish by-products are thus expected to become increasingly important as industrial feedstock (Table 1).

Enzymes

Aquatic invertebrates at large, as well as the internal organs of fish and the shells of crustaceans, constitute natural sources of enzymes with huge interest (Ferraro et al., 2010). The internal organs of the fish are a rich source of enzymes, many of which exhibit high catalytic activities at relatively low concentrations. The enzymes which are available in fish include: pepsin, trypsin, chymotrypsin and collagenase. These enzymes are commercially extracted from the fish viscera on a large scale (Ghaly et al., 2013). These enzymes are used in cheese, red meats, fruit juice, seafood processing and collagen removal for performing different functions.

Conclusion

Fish processing is one of the major industries in many countries. During the processing of fish, a significant amount of waste is generated which can be utilized as fish silage, fishmeal and fish sauce and other high-value products such as proteins, oil, chitin, chitosan, collagen, gelatin, hydroxyapatite, antifreeze proteins, astaxanthin, and enzymes. Further researches are needed to develop methods to apply them for human health promotion.

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