Chapter

Innovation in the Seafood Sector through the Valorization of By-Products

Marzieh Moosavi-Nasab, Najme Oliyaei, Jong-Bang Eun and Armin Mirzapour-Kouhdasht

Abstract

Aquatic, marine and algae, is reservoir of bioactive compounds, which have considerable potential to supply novel ingredients toward the development of commercial functional food products. Meanwhile, several valuable by-products generate during the manufacturing process. Seafood is still an intact reservoir of valuable compounds with significant potential to provide unique compounds applicable in functional food development. Seafood, as an important part of the diet all around the world, can be used as a source of functional components that are positively affecting the human health. Annually, 50–80 percent of the seafood processing is discarded as waste every year. Algae are also the novel natural resources for their biological and pharmacological properties. This chapter will be discussing the innovations in seafood and algae sector through the valorization of their by-products. Firstly, protein production, its characterization and the protein hydrolysates derived from seafood will be reviewed. Subsequently, bioactivity of the peptides obtained from these protein hydrolysates and other bioactive compounds such as carotenoid compounds derived from seafood including fish, shrimp, alga, and so on will be included. Finally, the main components of algae including sulfated polysaccharides, pigments and proteins will be surveyed.

Keywords: seafood by-products, algae by-products, bioactive compounds, protein, pigments, carotenoids, sulfated polysaccharides

1. Introduction

It is well-known that the seafood has been one of the most important parts of the human nutrition for a long time. According to reports obtained from FAO, the annual discard from global marine capture between 2010 and 2014 was 9.1 million tons. This huge amount of by-products represents 10.8% (10.1% –11.5%) of the annual average catch of 2010 to 2014 [1]. Utilizing this discarded part of the fishery industries could be environmentally and economically profitable.

Several value added products can be generated from seafood processing by-products depending on which kind of seafood is processed. Based on this, this chapter is divided into 3 major parts; (I) fish by-products, (II) crustaceans, and (III) seaweeds. This study has provided a review of use of fish by-products to produce some value added products including proteins, peptides, and oil. These products are the most

important major products that have a promising future in global market. During last decades, different efforts have been done to utilize the seafood by-products to generate these value added products [2]. Obtaining proteins and peptides as functional and nutritional compounds from seafood by-products have been the objective of many researches [3–9].

Algae are an important renewable source of food, medicines and fertilizers and their utilization have increased in all around the world. They are considered to possess a high nutritional value and their metabolites, and associated biological activities, have particular significance for multiple nutraceutical, cosmetic and pharmaceutical applications [10, 11]. Seaweed consumption has a long tradition in Asian countries and has increased in European countries in over recent decades, due to increased awareness of their beneficial effects [12]. Thus, development of way for the utilization of marine algae for food, feed, and bioenergy is essential. One of the best way is conversion of biomass into a variety of valuable products which is known as biorefinery [13].

In recent years, numerous compounds with biological activities or pharmacological properties such as antibacterial, anti-inflammatory, anticancer, antiviral and anticoagulant are discovered in algae. Algae by-products can be used for human and animal as food, animal feed and ingredients of dietary supplements. Sulfated polysaccharides, pigments, proteins and lipid are the main by-products of algae [12].

This chapter focuses on important value added bioactive chemicals identified in seafood by products over the last years and describes the range of biological activities as well as industrial applications for which they are responsible.

2. Fish by-products

2.1 Proteins

Fish by-products obtained from seafood processing industries contain huge amounts of head, skin, scales, bones, fins, viscera, and dark muscle. The protein content of these by-products is approximately 15%, which is similar to that of fish fillets. The muscle which is attached to this by-product contains two distinct type of proteins including structural (myofibrillar) (approximately 70–80%) and sarcoplasmic proteins (approximately 20–30%). These high nutritional value proteins (even more than red meat and milk casein) indicate remarkable functional and technological properties like water holding capacity, emulsifying activity, film forming ability, foam forming capacity, and gel forming ability [14–17]. Commercial gelatins are mostly obtained from mammalian (porcine and bovine) skins and bones. As the researches confirm, the substitution of mammalian gelatin with fish gelatin is an appropriate and appealing due to increasing concerns of researchers and consumers about the risks of transmission of the pathogenic vectors such as prions. Albeit, number of committees like the Scientific Steering Committee of the European Union, have stated that consumption of bovine bone gelatin is safe [18], researchers are still debating on this.

Nowadays, researches have become to notice on a unique protein which can be easily extracted from fish by-products especially skin, scales, bones, and fins. This valuable protein is collagen/gelatin. Collagen is the most abundant protein in tissues including skin and bones (approximately 30% of the total protein). The structural investigates show that collagen is a triple helix with three identical polypeptide chains. The primary structure of this protein is continuous repeating of the Gly-X-Y-sequence. The positions of X and Y are mostly proline and hydroxyproline, respectively. Different types of collagen (29 distinct types) have been discovered

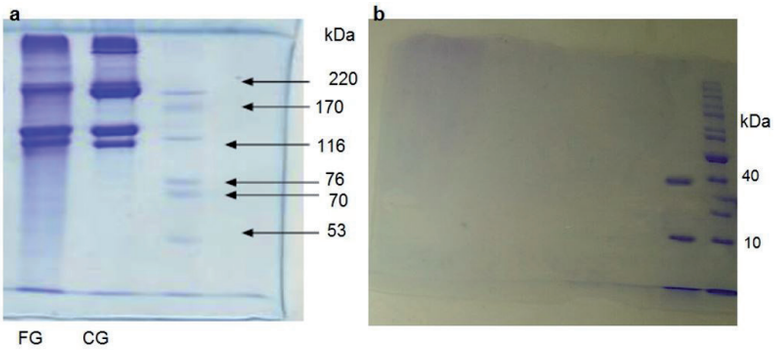

Figure 1.
Molecular weight distribution analysis by SDS-PAGE for gelatins. CG (commercial gelatin) and FG (fish wastes gelatin) (a) and for protease (b). Adapted from [23].

so far, which have right-handed triple helical conformation. The difference among these types is due to the variety in their amino acid sequences as a result of genetic variants [19–21]. Fish gelatin could be extracted from its by-products by a partially denaturation of collagen usually performed by hot water. Before extraction of fish by-products, some pretreatments are needed to ready them for being used as a gelatin source. The pretreatment step is ordinarily an alkaline and/or and acidic swelling process. The alkaline and/or acidic pretreatment is used to partial cleavage of rigid cross-links in the collagen and remove non-collagenous materials. The enzymatic aided chemical pretreatments are those which can be supplemented or replaced by enzymatic reaction. The "conditioning process" is the known name of this step by manufacturers of gelatin. Afterward, the gelatin (warm water soluble) will be extracted from collagen (not soluble) by hot water at a specific temperature and time. There are lots of studies performed in this research area. In a paper authored by Mirzapour-Kouhdasht, Moosavi-Nasab [22], gelatin was optimized at different levels of time and temperature using the response surface methodology (RSM). The responses including yield, protein content, gel strength, and viscosity indicated that the optimum conditions were 70.71°C and 5.85 h. Rheological, structural, and functional experiments showed that the gelatin characteristics were acceptable compared to the commercial bovine gelatin. The pretreatment in these experiments was performed by alkaline solution. In another study [23], gelatin was produced from Common carp wastes using alkaline protease from *Bacillus licheniformis* PTCC 1595. The enzymatic reaction was performed in 5, 10, 15, 20, and 25 units per gram of wastes. The molecular weight distribution of the gelatin (**Figure 1**) showed that this gelatin could be successively replace the commercial gelatin.

In some researches also fish gelatin is modified by some functional groups or chemical agents to improve the functional characteristics. In a study performed by [24], rheological, emulsifying, and structural properties of phosphorylated fish gelatin was investigated. The results of this study revealed that phosphorylation in a short time, enhances gel and rheological behavior of fish gelatin. Phosphorylation could improve the emulsions stability of fish gelatin as well. Authors stated that the structural properties of fish gelatin were significantly affected by this modification **Figure 2**.

2.2 Peptides

Peptides obtained from seafood processing by-products have been reported to have potent biological activities including antioxidant activity [25–31], antihypertensive, anticancer, anti-inflammatory, and anticoagulant properties [22, 32–37]. Among all these researches, the use of gelatin derived from fish by-products has

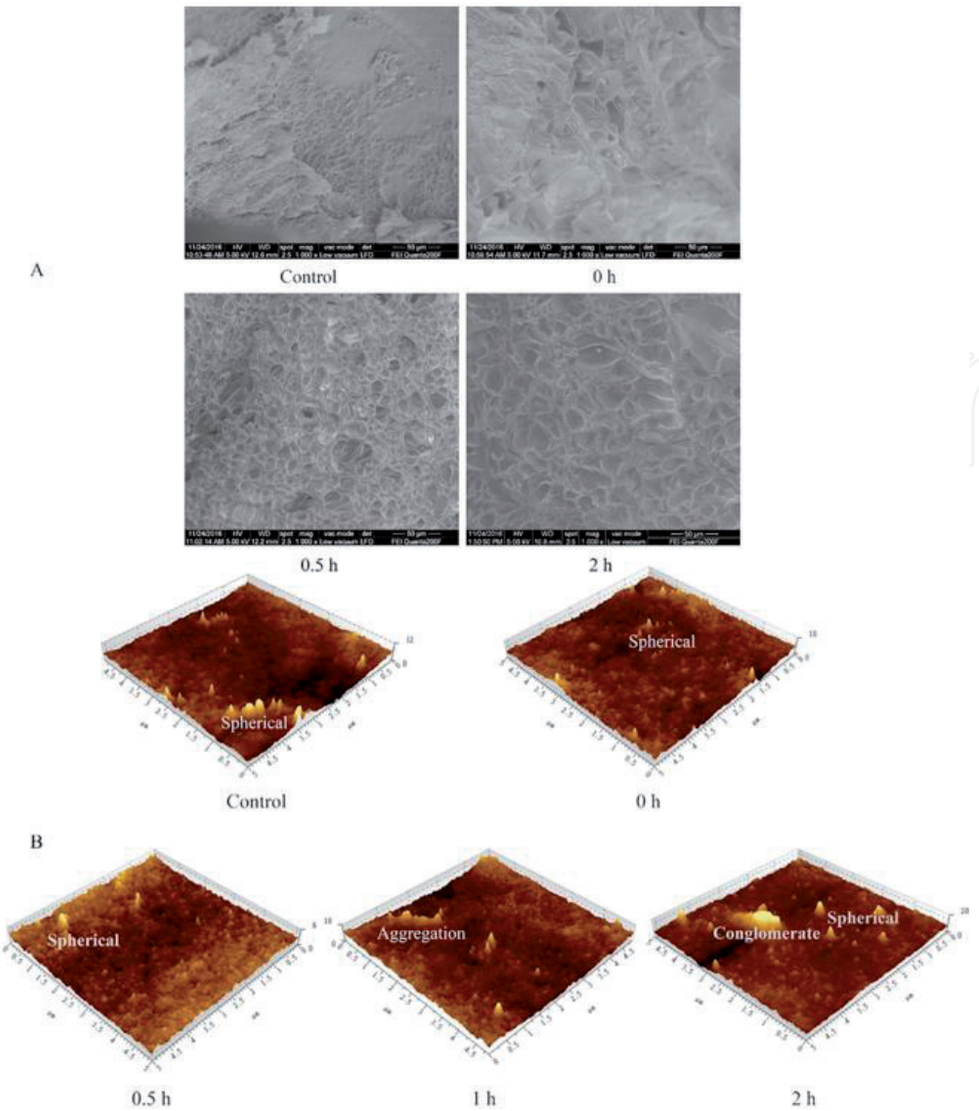

Figure 2.
Micrographs of control and phosphorylated fish gelatin. SEM (A) and AFM (B). Adapted from [24].

been well investigated as a source of bioactive peptides with various biological activities. In a study performed by Jin, Teng [38], salmon skin collagen was hydrolyzed by different proteolytic enzymes including pepsin, trypsin, papain, and Alcalase 2.4 L. Hydrolysates obtained from trypsin hydrolysis reaction indicated the highest dipeptidyl peptidase IV (DPP-IV) inhibitory activity (66.12%). After fractionation and identification processes, a bioactive peptide with sequence of LDKVFR for DPP-IV inhibitory activity was detected to be responsible for this activity (IC50 value of 0.1 ± 0.03 mg/mL). In another research conducted by Mirzapour-Kouhdasht and Moosavi-Nasab [39], gelatin extracted from *Scomberomorus commerson* skin in combination with its hydrolysates obtained by Actinidin from kiwifruit was used to extent the shelf-life of whole shrimp (*Penaeus merguiensis*). The results revealed that the gelatin hydrolysates can be applied as a preservative coating agent for whole shrimp.

2.3 Oil

Nowadays, of the most important nutritional substances which have gained much attention are Omega-3 long-chain polyunsaturated fatty acids (LCPUFA). These LCPUFA are necessary for human and animal physiology due to their

structural and regulatory functions [40]. Fish by-products are a good natural source of LCPUFA, especially EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). Fish oil is rich in vitamins (E, D, A). Due to these valuable components, fish oil consumption could be a promising way to impede some health risks such as inflammation, coronary heart diseases, obesity, arthritis, autoimmune disorders, and cancer [41–44].

Generally, the extraction of oils from fish by-products can be divided in two categories including conventional and modern methods. Generally, in conventional methods the raw material (fish by-products obtained from fish processing industries) are first cooked. After the cooking, the by-products are sieved followed by pressing for oil extraction. Subsequently the extracted slurry is decanted and the oil is stored in oil storing tanks [45].

In comparison with conventional extraction method, the modern extraction methods such as supercritical fluid extraction (SFE) could be useful for reducing the oxidation of LCPUFA. In a research performed by Rubio-Rodríguez and coworkers [46], SFE method with carbon dioxide under moderate conditions (25 MPa and 313 K) was used to extract oil from different fish by-products. They resulted that SFE is an advantageous method for oil extraction from fish by-products. The authors stated that the SFE can impede lipid oxidation and reduce extraction of impurities. In another study conducted by Sabzipour and others [47], quality of rainbow trout (*Oncorhynchus mykiss*) by-products oil was investigated. However, the aim of this study was to determine the effect of different postmortem processing times and blanching methods. The authors presented that the degradation of fish by-products oil occurs faster than the fish tissue oil. So they surveyed the effect of different treatments on the quality of the fish by-products oil. According to their report, salt blanching could decrease the effects of delayed processing and led to a higher quality.

However, the limitation of fish oil for utilization in food and pharmaceutical industries is related to the low stability and strong fishy flavor. The solution for this problem is to encapsulate the fish oil using different strategies to cover the off-flavor and also increase the stability. In a research performed by Drusch et al. [48], fish oil with was microencapsulated by spray-drying in a matrix of n-octenylsuccinate-derivatized starch and sugars. The results of this study indicated that this protocol can increase the oxidative stability of fish oil without any significant changes in physicochemical properties of the oil such as particle size, oil droplet size, and true density. Another study conducted by Chen et al. [49], the fish oil co-encapsulated with phytosterol ester and limonene, prepared by spray-drying and freeze-drying methods. The wall material used for encapsulation were whey protein isolate and soluble corn fiber. Sensory analysis of the encapsulated fish oil showed that the addition of limonene could cover the fishy flavor. The authors also reported that this procedure could significantly enhance the oxidative stability of the fish oil during 168 h of storage.

3. Crustaceans

3.1 Proteins and peptides

Tremendous amounts of shrimp processing by-products (head and body carapace) are discarded annually, which could be an important source of bioactive molecules. The amount of by-products generated during processing is about 48–56% of the whole shrimp depending on the species. The major composition of these by-products are protein (35–50%), polysaccharide (predominantly chitin) (15–25%),

minerals (10–15%), and a few percent carotenoids [50]. Recently production of bioactive peptides from shrimp by-products has gained attentions. Several researchers found that this source of by-products could be a good one to generate bioactive peptides with especial activities such as angiotensin converting enzyme inhibitory (ACE inhibitory) [51, 52], antimicrobial activity [53], antioxidant activity [52, 54], etc. More investigations are required to characterize the biological and functional properties of these peptides.

3.2 Chitin

The major value added product obtained from crustaceans is chitin which has the second position among frequent and used biopolymers in the world after cellulose [55, 56]. In fact, chitin is a polymer of β-(1 → 4)- *N* -acetyl- D–glucosamine units which is extracted mainly from shrimp and crabs. This polysaccharide could be found in arthropods exoskeleton or in the cell walls of fungi and yeast as the major prominent structural component [57–65]. Chitosan is a linear polysaccharide derived from chitin deacetylation [66]. Chitin and chitosan have attained lots of attentions due to their non-toxicity, biocompatibility, biodegradability, and low cost [56, 67]. Chitosan is known as a biologically active component in many fields such as food and pharmaceutical applications. A number of activities of this polysaccharide such as making delivery systems [68], tissue engineering [69], food packaging and film forming [70, 71], and antimicrobial and wound healing [72] are investigated.

One of the most important characteristics of chitosan which can affect its pharmaceutical and functional properties is the degree of acetylation. In case of designing delivery systems, the molecular weight of this bioactive molecule becomes more important due to changing the encapsulation efficiency [73]. It is very important to know that chitosan has a higher solubility in lower pH values due to protonation of the amino groups of the molecule [74]. Permeation enhancers substances can increase the absorption of encapsulated biological active compounds in the gastrointestinal tract. One of the mechanisms of this action is opening the tight junctions of the epithelium cells [75, 76]. Chitosan has a mucoadhesive nature and capable to open epithelial connections (tight junctions) of the epithelium cells [77, 78]. **Figure 3** shows a schematically the action place of permeation enhancers to increase the absorbance of bioactive components in gastrointestinal tract.

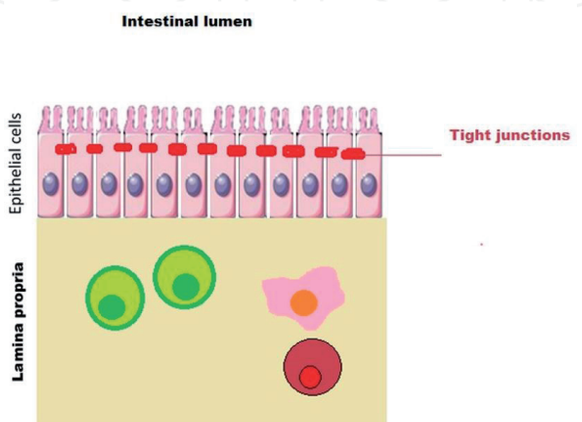

Figure 3.
The action place of permeation enhancers to increase the absorbance of bioactive components in gastrointestinal tract.

4. Algae

4.1 Sulfated polysaccharides

Phycocolloids or hydrocolloids are polysaccharides have been one of the most accessible and widely used in food industry as thickening and gel forming agent. Indeed, numerous sulfated polysaccharides from algae including agars, carrageenans and fucoidan (**Figure 4**) are the main bioactive components that have been determined to possess significant various biological activities [79].

Agar is polysaccharide comprised of two major components, agarose and agaropectin and has been extracted from seaweeds for industrial purposes in pharmaceutical, cosmetics and food industry as gelling and thickening agent [80]. The commercially used seaweeds for the extraction of agar are mainly *Gracilaria* and *Gelidium* species [81].

In addition, carrageenan is another linear sulfated polysaccharides that extracted from red seaweed and exhibits several applications in food industries as gelling, thickening, and emulsifying attributes, clarification of beer and wines. Carrageenan mainly obtain from two algae *Kappaphycus* and *Eucheuma* [82].

Fucoidans, a complex sulfated groups with fucose which found mainly in cell-wall matrix of brown macroalgae [83]. In addition to fucose, fucoidan contain other monosaccharides such as glucose, galactose, rhamnose, xylose, mannose and uronic acids [84]. Numerous brown seaweeds have been used for fucoidan extraction including *Sargassum* [85, 86], *Undaria* [87], *Laminaria* [88], *Cladosiphon* [89], *Fucus* [90], *Saccharina* [91] and *Ascophyllum* [92]. Several investigations have been confirmed the biological activities of fucoidan including antitumor, anticoagulant, antioxidant, immunomodulatory, anti-inflammatory, antiviral, antithrombotic, and hepatoprotective effects [93, 94]. This bioactivity of fucoidan is depend on its molecular weight, the monosaccharide composition, the sulfate content, the position of the sulfate ester group, the extraction technique, and fucoidan structure [94]. Thus, several extraction techniques are used such as conventional methods (hot water) [95] and non-conventional methods such as pressurized liquid extraction [84], ultrasound [96], enzyme assisted [90], microwave assisted [97] and subcritical water [91] extraction.

Subsequently, the green algae *Monostroma nitidum* is the commercial source of a sulfated polysaccharide named rhamnan sulfate [98]. Rhamnan sulfate found in

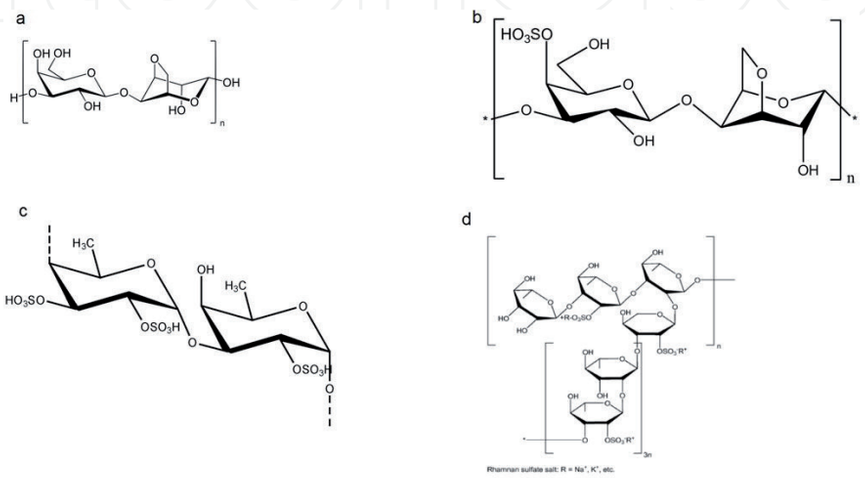

Figure 4.
The chemical structure of (a) agar; (b) carrageenan, (c) fucoidan and (d) Rhamnan sulfate.

cell wall of *M. nitidum* and structurally consists of rhamnose with a sulfate-group substituent that forms main chains with branched side chains [98, 99].

This polysaccharide is extracted by hot water, though is poorly water soluble [100]. Several studies exhibit its biological activities such as antiviral, anticoagulant, antitumor, anti-inflammatory, anti-hypercholesterolemic, anti-obesity and anti-hypertensive properties. Further, *M. nitidum*-derived rhamnan sulfate is considered to promote the human health [100].

Calcium spirulan (Ca-SP) is another novel sulfated polysaccharide isolated from blue-green alga Spirulina platensis. Ca-SP is an attractive candidate therapeutic agent for viral infectious diseases because of its antivirus and antitumor activities [101, 102].

4.2 Pigments

4.2.1 Carotenoids

Carotenoids and chlorophylls are generally wasted together with the residual biomass during the extraction of phycocyanin or sulfated polysaccharide, while can isolate as valuable product from algae [103].

Carotenoids are the most widespread class of pigments that are characterized as natural colorant and antioxidants with healthy effects including anti-cancer, anti-diabetic anti-obesity and eye diseases. The bio-functional properties of algal carotenoids make them potentially to use in nutraceuticals, cosmeceuticals and feed supplements in aquaculture sectors. Carotenoids divided into primary and secondary based on their metabolism and function. Primary carotenoids are structural and functional components in the photosynthetic apparatus, which take direct part in photosynthesis. Secondary carotenoids refer to extra-plastidic pigments produced in large quantities, through carotenogenesis, after exposure to specific environmental stimuli [104].

Microalgae are a potential renewable resource of primary and secondary carotenoids. α-carotene, β-carotene, lutein, fucoxanthin, violaxanthin, zeaxanthin, and neoxanthin, are characterized as primary carotenoids while astaxanthin, canthaxanthin, and echinenone are secondary carotenoids. Astaxanthin, zeaxanthin, fucoxanthin and lutein receive much attention as commercial carotenoids [104].

Seaweeds are the important sources of bioactive compounds which have several human health benefits. The most predominant seaweed carotenoids, such as fucoxanthin, lutein, β-carotene and siphonaxanthin have remarkable biological functions and applications [105]. Pigments are waste during the polysaccharide extraction process. Thus, carotenoids are recovered from microalgae and seaweeds by different approaches including conventional solvent extraction, non-conventional methods including pulsed electric field [106, 107], moderate electric field [108], supercritical fluid extraction [109], pressurized liquid extraction [110], microwave ssisted extraction [111, 112], ultrasound assisted extraction [113], high pressure homogenization [114].

Fucoxanthin ($C_{42}H_{58}O_6$) is the predominant carotenoid in brown algae (*Sargassum angustifolium*, *Laminaria japonica* and *Undaria pinnatifida*) and some microalgae (*Phaeodactylum tricornutum*, *Isochrysis galbana*, *Odontella aurita*) that accounting for more than 10% of the estimated total natural production of carotenoids. This yellowish-brown pigment exhibit remarkable biological properties, including anticancer, anti-inflammatory, antiobesity and neuroprotective activity [115–117]. Moreover, fucoxanthin extraction can be by-product of fucoidan extraction process as Yip et al., [118] obtained the fucoxanthin-rich extract from *S. binderi* with yield of 7.4 ± 0.4 mg/g.

Astaxanthin as king of antioxidant is found in microalgae such as *Haematococcus*. *H. pluvialis* is rich in astaxanthin and provide a natural and inexpensive source of astaxanthin [119]. The antioxidant activity of astaxanthin is 100 and 10 times greater than those of vitamin E and β-carotene. Moreover, astaxanthin has a superior preventive effect toward photo-oxidative compared with canthaxanthin, and β-carotene [120].

4.2.2 Phycobiliproteins

Phycobiliproteins are natural fluorescent dyes which participate in photosynthesis. These pigments are assembled large, distinct granules as phycobilisomes, which are attached to the thylakoid membrane of chloroplast. These pigment-protein complex plays an important role in light-harvesting in cyanobacteria, red algae cryptomonads, glaucophytes and some pyrrophyceae [121, 122]. Phycobiliproteins are divided into two main groups; phycoerythrin (PE –bright pink red), phycocyanin (PC –deep blue). The main components of phycocyanins are C-phycocyanin (C-PC), R-phycocyanin (R-PC), and allophycocyanin (AP – bluish green) [121, 122]. Moreover, there are differences between in their structural position. PE is at the tip of the rod-like phycobilisomes, PC is in the middle, while AP forms a core attached to the reaction and energy transfer proceeds successively from PE to PC to AP and to chlorophyll [123]. The other classification of phycobiliproteins is based on their spectral attributes which including phycoerythrobilin (PEB, A max 560 nm), phycocyanobilin (PCB, A max 620–650 nm), phycobiliviolin (PXB, A max 575 nm) and phycourobilin (PUB, A max 498 nm) [123]. These biopigments have attracted much attention in medicines, foods, cosmetics and fluorescent materials. The recent research has brought attention to the use of phycobiliproteins as food colorant, health drink and coloring agent in confectionary and cosmetics because they are hydrophilic and stable at low temperature with some preservative like citric acid, in acidic and basic solutions [121, 123]. Moreover, phycobiliproteins are used in diagnostic kits in immunology as fluorescent tracer of antibodies [123] and gel electrophoresis and gel exclusion chromatography as marker because of their high molecular absorptivity at visible wavelengths [122].

Phycocyanins have an apparent molecular mass of 140–210 kD and two subunits, α and β [124]. C-Phycocyanin is found in cyanobacteria strains such as *Spirulina* sp. (freshwater), *Phormidium* sp. (marine water) and *Lyngbya* sp. (marine water) [125]. However, the commercial source of this pigment is *Spirulina* which consists of about 20% of the dry weight of this algae [126]. Further, the other new source of phycocyanin is *Anabaena oryzae* SOS13 [124, 127].

Recent studies have demonstrated the role of C-PC as antioxidant, anti-inflammatory, hepatoprotective, and as well as free radical scavenger [128, 129]. Various techniques are used to extract phycocyanin from *Arthrospira platensis* (*Spirulina*) biomass including in various approaches such as physical (freeze–thaw) or an enzymatic (lysozyme) [124], supercritical fluid extraction [130] andsonication and microwave [131].

Phycoerythrin also have numerous health benefits, however, the absorption spectrum of cyanobacteria phycoerythrin is deferent from red algae. The cyanobacteria phycoerythrin exhibits a single peak at 565 nm in the visible wavelength region, while the absorption spectrum of red algae phycoerythrin includes three peaks in the visible wavelength region at 500, 550 and 565 nm (R-phycoerythrin) [123].

Allophycocyanin is a light-harvesting pigment protein complex found mainly in *A. platensis*. This water-soluble pigment is broadly used in biochemical techniques such as a fluorescent probe, especially for flow cytometry. Further, allophycocyanin

has promising applications as antioxidative, anti-inflammatory, antitumor, anti-enterovirus and hepatoprotective [132]. Despite its potential biochemical and therapeutic benefits, there are some challenges in its downstream processing including difficulty in primary extraction and purification, containing lower proportion of phycobiliprotein rather than phycocyanin and the resistance of cell membrane to disruption cause extraction of 50–60% of A-PC by conventional methods. Moreover, the main objective of pigment extraction form *spirulina* is C-PC, consequently, remaining high content of A-PC (about 40–50%) in biomass after C-PC extraction [133].

4.3 Proteins

Algae protein waste is a by-product derived from water-extraction process of microalgae, during algae essence manufacturing. The underutilized algae wastes, containing above 50% protein, have low economical value to be used as animal feed. The pepsin hydrolysate from algae protein waste exhibited antioxidative activity in preliminary experiments, indicating that algae waste might become a new protein source for selection of novel antioxidative peptides [134].

Furthermore, protein hydrolysates from marine sources such as algae by-products, have generally been used to produce seafood flavorings. A high flavor quality is difficult to ensure for seafood flavoring that is produced from marine animal sources because of their high susceptibility to lipid oxidation and the high cost of removing excess fat. Seaweed by-products after agar extraction are good sources of plant protein and contain taste-active amino acids, such as aspartic acid, glutamic acid, arginine, and lysine, in addition to a low fat content [135].

A seaweed protein hydrolysate using 10% bromelain for 3 h, resulted in high level of arginine, lysine, and leucine as free amino acids. These amino acids exhibited an umami taste and a seaweed odor [135].

Most microalgae contain high level of protein which discarded or damaged during biofuels production, while are good candidate for protein extraction and consequently, obtain lipid-rich product as by-product as feedstock for biofuels production. Even though proteins are major algae biomass component, usually they are undervalued compared to minor components such as omega fatty acids, pigments or other possible valuable buy-products [136].

For instance, Garcia-Moscoso et al. [136] extracted more than 60 wt% of nitrogen content of *Scenedesmus* sp. by subcritical water medium then the lipid-rich residue used as suitable feedstock for biofuel production.

There are numerous investigations about algae protein waste and extraction of peptides or amino acids with functional properties. For instance, the antioxidative peptide of VECYGPNRPQF was isolated by pepsin from *Chlorella vulgaris*. This peptide had some bioactivity such as DNA protective effect against hydroxyl radicals, gastrointestinal enzyme-resistance, and strong antioxidant properties. Fractionation of proteins exhibited the high level of aspartic acid, glutamic acid, leucine and lysine [134]. This amino acid sequence (VECYGPNRPQF) can act as cheap and natural anticancer peptide because had antiproliferation and induced a post-G1 cell cycle arrest in AGS cells with no cytotoxicity effect in WI-38 lung fibroblasts cells [137].

Moreover, protein isolation, as valuable by-product, from defatted *Nannochloropsis*, can be obtained after lipid extraction during biofuel production. Defatted and non-defatted *Nannochloropsis* contained 56.9% and 40.5% protein respectively. The protein yields by alkaline (pH 11 and 60 C) extraction method were 16% and 30% respectively. These isolated proteins had a high molecular weight approximately 250 kDa [138].

Macroalgae are also a suitable protein source and rich in protein after extraction of their polysaccharide, lipid and polyphenols. Among three seaweed *Porphyra umbilicalis*, *Ulva lactuca*, and *Saccharina latissimi*, the highest protein isolated using pH- shift method (71%) was related to the *P. umbilicalis*. Furthermore, among different extraction methods including pH-shift method, accelerated solvent extraction and sonication in water and precipitation by ammonium sulfate, pH shift process is promising approach. However, the yield and extraction approach are influence by type and species of seaweed [139].

Brown algae such as *Laurencia filiformis*, *L. intricata*, *Gracilaria domingensis* and *Gracilaria. birdiae* can supply dietary proteins for human and animals because their protein content reported 18.3, 4.6, 6.2 and 7.1% respectively [140].

Combination of acid-alkaline process is another protein isolation from algae. First acid and then alkaline extraction is an alternative extraction by 59% protein recovery from brown seaweed *Ascophyllum nodosum*. The obtained protein had about 2–4 kDa molecular weight [141].

5. Conclusions

This chapter indicated that seafood by-products are one of the most important sources of value added products that can play an important role in the global market due to the increasing growth of demands for health beneficiary products. Through this opportunity and based on our research background for many years, we decided to provide important information about some value-added products obtained from seafood by-products. Proteins and peptides are a major part of the seafood by-products composition that can easily provide essential amino acids and bioactive peptides with health beneficent. Fish oil is another valuable product that could be extracted from seafood by-products. This source is rich in LCPUFA and decreases the risks of chronic diseases such as cardiovascular issues, thereby directly related to our health. Marine algae are a versatile, abundant, and valuable source of many compounds that have been widely used for many industries. The presence of bioactive compounds such as sulfated polysaccharide, carotenoid, and protein makes them a suitable candidate in biomedical applications. It seems, they will play an important role in human life because of their broad applications in food, pharmaceutical, and cosmetic industries.

Conflict of interest

The authors declare no conflict of interest.

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