Bioactive compounds from Marine Sources

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Introduction

Bioactive compounds are phytochemicals, which can modulate metabolic processes, promoting improved health to humans. Bioactive compounds have multiple biological effects including antioxidant, antimutagenic, anticarcinogenic, antiallergenic, anti-inflammatory and antimicrobial activities. Marine sources serve as a rich source of functional materials such as collagen, gelatin, polyunsaturated fatty acids, polysaccharides, pigments, enzymes, vitamins and minerals. Bioactive compounds from marine sources have been a major effect on many research groups in the world. However, marine sources are still considered as a relatively unexploited source of functional materials. Microalgae are one of the most promising sources for developing eco-sustainable production of natural bioactive metabolites.

Since oceans occupy more than 70 % of the earth surface, their high level of biodiversity makes them a logical target for looking for natural products. Marine bioactive constituents can be obtained from various marine organism includes animals, sponges, ascidians, mollusks, sea anemones, and seaweeds. Among the marine sources, seafood wastes and seaweed were considered an important source for the extraction of bioactive compounds at industrial production. Currently, seafood wastes were utilized to produce fish oil, fish meal, fertilizer, pet food and fish silage in India. However, recent research works were mainly focused for bioactive compounds such as bioactive peptides, collagen, omega 3 fatty acids oligosaccharides, enzymes for biotechnological and pharmaceutical applications. The majority of bioactive compounds from marine sources were made up of protein, lipid and polysaccharide. The procedure for isolation of bioactive compounds and their sources is mentioned in Figure 1 and Table 1

Protein based bioactive compounds

Proteins are complex polymers made up of a combination of 20 different amino acids coded by the genetic (DNA) code and several other amino acids.

Marine Proteins

Fish protein is the second major constituent after water in fish and present in the range of 16-18 %. The quality and the wholesomeness of the fish is determined by fish protein. The fish proteins are classified as myofibrillar, sarcoplasmic and stroma protein. Sarcoplasmic proteins are water soluble proteins include enzymes, pigments, heme proteins, myoglobin, hemocyanins and antifreeze proteins. Stroma proteins are structural proteins or connective tissue proteins insoluble in salt solutions. The myofibrillar protein is responsible for the structural organization of the muscle and account for about 65 – 75% of total fish muscle proteins. They are soluble in high ionic strength salt solutions.

Fish muscle proteins and microalgae contains all the essential amino acids in close to the right proportions for humans. Spirulina, for example, has high protein content (60 % to 70 %), with great balance of the essential amino acids and bioavailability. Spirulina appears to be one of the most important microalgae used by humans. A daily supplement of Spirulina is believed to reduce allergy symptoms in human being.

Collagen

Collagen molecules, composed of three a-chains intertwined in the so-called collagen triple-helix, adopt a 3D structure that provides an ideal geometry for inter-chain hydrogen bonding. The triple-helix of collagen is approximately 300 nm in length, and the chain has a molecular weight of approximately 10^5 kDa. The triple helices are stabilized by the aforementioned inter-chain hydrogen bonds. Fish have lower concentrations of imino acids (proline and hydroxyproline) compared to mammalian collagen. Total or partial separation of the chains due to destruction of the hydrogen bonds, causing loss of the triple-helix conformation, and following denaturation, the polymers exist in a coiled form.

Fish collagen have numerous applications such as, pharmaceutical/biomedical applications (as anchor in glass, beads for cell culture, biomaterial for vascular prosthesis, microparticles for subcutaneous injection, scaffold in tissue regeneration, as feed/food (gelatin,glue), cosmetics, and to produce collagen hydrolysates (used in oral administration).

Gelatin

Gelatin is the denatured form of biopolymer derived by thermal hydrolysis of fibrous protein collagen. It is the principal constituent of animal skin, bone, and connective tissue. Gelatin is produced via the partial hydrolysis of native collagen. Gelatin is slightly differed from collagen in its chemical composition. The triple helical structure of collagen made up of three α-chains, whereas gelatin comprises three different chains viz., α-chain, β-chain and γ-chain. α-chain (one polymer chain), β-chain (two α -chains covalently crosslinked), and γ-chain (three covalently crosslinked α-chains). Gelatin is mainly composed of three amino acid repeat motif, Glycine-Proline-Hydroxyproline. The functional properties of gelatin and stability of triple helix are mainly governed by the proline and hydroxyproline content.

Gelatin is used in several applications as an emulsifier, stabilizer, wetting agent, fining agent, biodegradable packaging films, microencapsulating agent due to their functional properties such as viscosity, gel strength, gelling and melting points. Apart from food industries, it also used in photographic, pharmaceutical and cosmetic field. Nowadays, aquatic animal sources are gained interest for gelatin production because of several hindrances such as religious constraint, disease and vector transmitting medium of terrestrial animal source.

Marine Peptides

Peptides are important bioactive natural products which are present in many marine species. These marine peptides have high potential nutraceutical and medicinal values because of their broad spectra of bioactivities. The beneficial effects of marine bioactive peptides include scavenging reactive oxygen species (ROS) and preventing lipid peroxidation. In the last few years, different studies have isolated, characterized and purified bioactive peptides from different marine sources with anti-oxidant potential. Peptides present in enzymatically digested protein hydrolysates exhibited different physiochemical properties and biological activities.

Bioactive peptides generally include 3 -20 amino acid residues, and their biological activities are based on their molecular weights and amino acid sequences. Antimicrobial peptides usually have less than 50 amino acids, of which about 50% are hydrophobic and have a molecular weight of below 10kDa. The antioxidant activity of peptides influenced by the hydrophobicity/hydrophilicity, amino acid sequences, degree of hydrolysis, and molecular weight of peptides.

Bioactive peptides or protein hydrolysates can be extracted and isolated from the protein of the marine species by various methods in industrial-scale production. Organic solvent extraction method was used traditionally, but it is a time-consuming, expensive and environmental unfriendly technique. Nowadays, better extraction techniques like supercritical fluid extraction, pressurized solvent extraction, microwave-assisted extraction, ultrasound-assisted extraction, pulsed electric field-assisted extraction and enzyme-assisted extraction are preferred. After the extraction procedure, the proteins are subjected to hydrolysis by which the proteins are hydrolyzed into bioactive peptides. Enzymatic hydrolysis is preferred in the nutraceutical and pharmaceutical industries in order to avoid harsh chemical and physical treatment and preserve the functionality and nutritive values.

Amino Acids

Seafood muscles are abundant in taurine, glutamic acid, glycine, proline, alanine and arginine. Fish is a good source of taurine a conditionally essential amino acid that has been shown to be involved in certain aspects of human development. It is assumed that consuming muscle proteins from fish are high in certain amino acids may improve human nutrition by boosting the nutritional value of foods.

Free amino acids usually interact with free radicals but the most efficient are the onces that can easily give away hydrogen atoms which include the amino acids having nucleophilic sulfur-containing side chains - cysteine and methionine or aromatic side chains (Tryptophan, Tyrosine, and Phenylalanine). This implies the specific compounds responsible for bioactivity of fish amino acids are Cysteine, Methionine, Lysine, Taurine, Tryptophan, Tyrosine, and Phenylalanine. Also, Glutamic acid, Proline, Glycine, Alanine and Arginine.

Minerals

Fish frames and bones would be a great potential source of high quantity minerals. In the total mass of fish bone nearly 60-70% is made up of minerals such as calcium, phosphorous and hydroxyapatite. Consumption of small fish along with bones in the regular diet will prevent the calcium deficiency. Since fish bones are the good source of hydroxyapatite, it can be extracted from fish processing waste. It is mainly used in medical and dental field as a bone graft material for produce artificial bone.

Enzymes

Presence of several proteases in fish viscera make it as a good source for the digestive enzyme viz., pepsin, trypsin, chymotrypsin and collagenase. Most of these enzymes were exhibit high catalytic activities even at low concentration. The internal organs would be used for extracting the enzymes in large scale.

Natural Pigments

The photosynthetic pigments are bioactive compounds that are able to capture solar energy. They are used by autotrophs for photosynthesis. For macroalgae, the major pigments are carotenoids and chlorophylls. These pigments are formed by algae, plants, fungi, and other microorganisms; however, humans and animals require ingesting them in their diets. Dietary carotenoids have nutritional and therapeutic importance since they act as provitamin A, which is converted into vitamin A. Carotenoids are known to be active agents for the protection against cancer, Cardio vascular disease, and macular degeneration. Microalgal formation of carotenoids, including β-carotene and astaxanthin, is an active area of research as they can be present at relatively high concentrations. β-Carotene is one of the major natural colorants and it has been employed to a vast spectrum of food and drinks in order to enhance their aspect. Moreover, β-carotene with intense antioxidant properties helps to reduce the harmful effects of free radicals, which have been related to various life-threatening conditions, such as different kinds of cancer, CHD, premature aging, and arthritis.

Lipids and fatty acids

The long-chain omega-3 fatty acids such as eicosapentaenoic acid (EPA, C20:5) or docosahexaenoic acid (DHA, C22:6) are the most common omega-3 fatty acids generated from marine sources which have been well documented as essential for human health. Humans are incapable of synthesizing PUFAs with more than 18 carbons thus, they should get them from food. Seafood are the major sources of long-chain PUFAs, although the synthesis actually occurs in the algae eaten by the fish. The amount and composition of these oils depend on the species, season and location of catching sites. The long chain fatty acids help to regulate the blood clotting and blood pressure, and develop function of the brain and nervous systems. They also decrease the risk of many chronic diseases such as arthritis, diabetes and obesity. Moreover, PUFAs regulate inflammatory responses by producing inflammation mediators called eicosanoids (Lordan and others 2011). The rate of omega-3 to omega-6 of macroalgae is close to ideal, therefore they are used as dietary complement as part of a balanced diet.

Sterols

Another class of lipids from marine sources is the sterol compounds. ergosterol, clionasterol, fucosterol and cholesterol are some of the sterols present in the seafoods. Cholesterol is the major sterol in fish, shrimp and lobsters. Fucosterol, chondrillasterol, and sargasterol are found in brown algae and cholesterol has been found in red algae.

Marine polysaccharides

Marine polysaccharides including alginate, porphyran, fucoidan, chitin, and chitin derivatives, are used as down regulators of allergic responses. Polysaccharides isolated from algae that are mostly sulfated exhibit anti-infammatory activity in vitro and in vivo, which attributes to their structure and physicochemical characteristics.

Chitin

Chitin is the second most important natural polymer in the world. The main sources exploited are two marine crustaceans, shrimp and crabs. Chitin and its derivatives is the major by product from crustacean processing. Chitin or poly (β-(1→4)-*N*-acetyl-D-glucosamine) is a natural polysaccharide. This biopolymer is synthesized by enormous number of living organisms and it belongs to the most abundant natural polymers, after cellulose. In the native state, chitin occurs as ordered crystalline microfibrils which form structural components in the exoskeleton of arthropods or in the cell walls of fungi and yeast.

Chitosan

Chitosan is the most important derivative of chitin. The term chitosan usually refers to a family of polymers obtained after chitin deacetylation to varying degrees. In fact, the acetylation degree, which reflects the balance between the N-acetyl glucosamine and D-glucosamine residues, differentiates chitin from chitosan. When the Degree of acetylation is lower than 50%, the product is named chitosan and becomes soluble in acidic aqueous solutions. Chitin can be converted to chitosan by enzymatic preparations or chemical process.

Chemical methods are used extensively for commercial purpose of chitosan preparation because of their low cost and suitability to mass production.

Chitin and chitosan offer a wide range of application from the agriculture to pharmacy industry due to its specific properties like bioactivity, biodegradability, chelation ability, absorption capacity and film forming ability. Although the chitin and chitosan are known to have very interesting physicochemical, functional and biological properties in many areas, their molecular weight and their solubility property restrict their usage. Chitosan, which is soluble in acidic aqueous media, is used in many applications (food, cosmetics, biomedical and pharmaceutical applications). Unfortunately, all chitin and chitosan are not applicable in all sectors owing to its high molecular mass, high viscosity and, thus, low absorption for in vivo applications. The effectiveness of chitosan in various applications appears to be dependent on the degrees of acetylation. Recent studies on chitosan derivatives like Water soluble chitosan, chitooligosaccharides have drawn considerable attention, since the products obtained have been easily water soluble and also possess versatile.

Chitooligosaccharides

The depolymerised form of chitosans is called as chitosan oligomers or chitooligomers, or chitooligosaccharide (COS). COS has been paid great interest in pharmaceutical and medicinal applications due to their high solubility and non-toxicity.

Carboxy methyl Chitosan

Carboxy methyl chitosan (CM-chitosan) is the most fully explored derivative of chitosan. This derivative is water soluble in a wide range of pH, only if prepared from a fully acetylated chitin.

Hydroxy propyl Chitosan

Hydroxypropyl chitosan (HPCS), a kind of water-soluble functional derivative of chitosan, is obtained by means of etherification through propylene oxide at the C6/C3 position under alkali conditions. Application of HPCS includes drug delivery, tissue engineering and wound healing.

Phosphorylated Chitosan

Through phosphorylation chitosan is converted to the form of Phosphorylated Chitosan. This derivative is important due to its interesting biological and chemical properties and it also exhibits bactericidal and osteoinductive properties.

Glucosamine hydrochloride

Glucosamine in the form of glucosamine sulphate, glucosamine hydrochloride, or N-acetyl-glucosamine is extensively used as a dietary supplement in the treatment for osteoarthritis, knee pain, and back pain, and a critical evaluation indicated that glucosamine is safe and does not affect glucose metabolism.

Glucosaminoglycans

Glycosaminoglycans (GAGs) are heteropolysaccharides consist of a repeating disaccharide unit without branched chains in which one of the two monosaccharides is always an amino sugar (N-acetylgalactosamine or N-acetylglucosamine) and the other one is a uronic acid. It possesses significant antioxidant and antihypertensive properties and could be utilized as natural preservative ingredient in functional foods and in pharmaceutical industry.

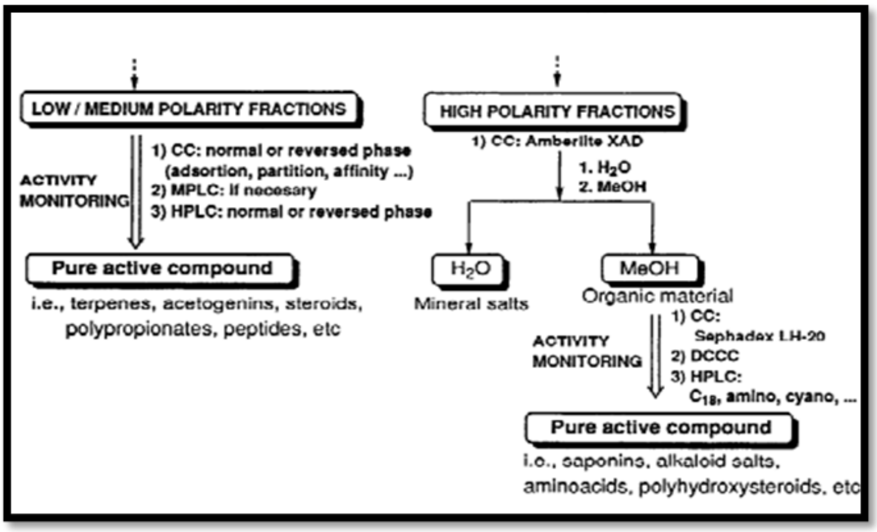

Figure 1: Procedure for isolating bioactive compounds from low/medium and high polarity fractions (adopted from Ricardo Riguera, 1997).

Table 1: Potential bioactive compounds obtained from different marine sources

S.No	Marine sources	Bioactive compounds
1	Sponges	Peptides
2	Marine microorganism	Protein, Vitamin B, Vitamin E and natural pigment
3	Seaweed	Peptides, Amino acids, Sterols, polysaccharide, vitamins, minerals
4	Cnidarians	Phenolic compounds
5	Bryozoans	Alkaloids
6	Molluscs	Proteins, Polypropionates
7	Tunicates	Peptides, Alkaloids
8	Echinoderms	Sterols, Alkaloids, natural pigments
9	Marine fishes and marine mammals	Fish oil, PUFA,Vitamins, Minerals
10	Crustaceans	Chitin, chitosan and its derivaties, pigments, minerals

Conclusion

Marine resources offer important bioactive molecules that have advantages on the human body. They can be applied in many fields such as the drug, cosmetic, and food industries. Functional foods can easily be developed from marine products since they are widely available and they have the ability to prevent certain diseases and cure some illnesses. Various kinds of seafood are consumed as nutritionally beneficial food. The sea offers an enormous resource for finding novel compounds, and it is considered as the largest remaining reservoir of natural molecules that may be used as functional ingredients in the food industry. Consequently, efforts should be made to develop marine functional foods responsibly, since their consumption could result in a decrease of the occurrence and gravity of chronic diseases.