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Review Article

Marine-Based Nutraceuticals vis-à-vis Therapeutic Potential: A Summary

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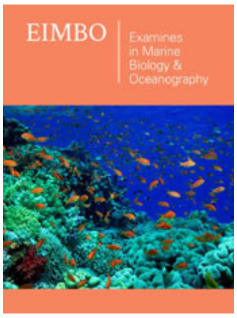

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Abstract

Great attention is being paid to the natural sources which provide functional bioactive compounds having nutraceutical and food supplement value, and health benefits for prevention and treatment of diseases. Marine ecosystems have a high diversity as compared to terrestrial ecosystem. The interest in biologically active molecules from marine sources is increasing. These bioactive molecules include certain polysaccharides, several phytochemicals, pigments, peptides, fatty acids, vitamin and mineral nutrients. Production of secondary metabolites is an important phenomenon with respect to its adaption mechanism to marine ecosystem and they are drug precursors. Marine invertebrates are a diverse group and a reservoir of number of biologically active molecules. This review describes in brief the recent studies on these primary and secondary metabolites with reference to their potential use as nutraceuticals and health care.

Keywords: Nutraceuticals; Biologically active molecules; Marine ecosystem; Health benefits

Introduction

Marine systems have a greater biodiversity of living organisms than terrestrial ecosystem, providing numerous bioresources for human health. The subject has received great attention because of its unique properties supplying a range of marine-derived bioactive compounds useful as nutraceuticals and food supplements [1]. The diverse group present in the marine ecosystems include microalgae, macroalgae, bacteria, cyanobacteria, fish, and crustaceans which produce several primary as well as secondary metabolites as drug precursors. The bioactive compounds contain primary metabolites viz. polysaccharides, peptides, phytochemicals, vitamins, polyunsaturated fatty acids, minerals (selenium and iodine) and other bioactive compounds such as carotenoids and taurine [2]. Beside these many other active compounds are obtained from marine sources which are used as pharmaceuticals and nutraceuticals.

In recent years, functional and bioactive compounds from natural sources such as terrestrial and marine plants, animals, or even microorganisms have become a potential source, which offers biologically active natural products [3]. Modern dietary habits and life style has increased the number diseases such as type 2 diabetes mellitus, obesity, metabolic syndrome, cancer, neurodegenerative diseases etc. [4]. The natural product mediated bioactive compounds have become an alternative to potentially harmful synthetic compounds having numerous side effects.

The diverse and dynamic nature of marine ecosystems have made the marine products a reservoir of new molecules for the development of nutraceuticals and disease specific drugs. More than 20,000 bioactive molecules have been isolated from marine sources, however, only few of them have been thoroughly studied and exploited to some degree [5]. Synthetic chemical drugs are found to be very active in treatment of different disorder involving immunity, allergic reactions, cardiovascular diseases, cancers or as immunosuppressant during transplantation etc. Health concern remains because of the possible side effect of synthetic medicines due to misuse, overuse and uncontrolled application of these chemical compounds [3]. Nutraceuticals from natural products can prevent or treat numerous ailments and improve the quality of life without any adverse effect. The safe nature of the marine-based nutraceuticals makes them suitable alternative of synthetic drugs [6]. A range of marine organisms including fish, algae, crustaceans, sponges, molluscs, actinomycetes, fungi and many other microorganisms have been exploited as potential source of natural products. Marine microorganisms are novel source of bioactive substance viz. natural antioxidants, immunosuppressants enzyme inhibitors, hypocholesterolaemic agents, vitamins, antibiotics etc (7Gupta and Prakash,). All of them are not biologically active, but they have beneficial influence on human health. Although many of them have biological properties but they are prone to deterioration. Nanoencapsulation of such compounds will be a potential proposition to protect these compounds and enhance their bioavailability [3]. Marine molecules are vast in number. Given below are the bio-chemical nature and functions of the major bioactive compounds.

Chitin and chitosan

Naturally occurring polymers with crystalline forms. While chitins are obtainable from exoskeleton of crustaceans, molluscs, insect and fungi, the main sources of chitosan are by-products of seafood processing, such as crab shells and shrimp/ prawn exoskeletons. Chitin and chitosan are natural polymers with same chemical structure. Chitin is water insoluble while chitosan is soluble in an acidic environment due to presence of free protonable amino groups in the D-glucosamine units [7,8]. Chitosan has three types of reactive functional groups, an anamine/acetamide, as well as both primary and secondary hydroxyl group [3]. Oxidative stress can damage cellular macromolecules and can lead to a range of health disorders including cancer. Chitosan and its derivatives due to their antioxidant properties can prevent oxidative damage by breaking the radical oxidation chain reaction [9].

Chitosan and its derivatives have potential antimicrobial activity which is due to polycationic nature of the polymer and their interaction with negatively charged microorganisms, leading to leakage of cellular substances and death of the microbes [10]. Chitosan has higher microbial activity as compared to chitin as the former one has higher number of positively charged amino groups [11]. Antimicrobial activity of chitosan and chitin is influenced by molecular weight, degree of deacetylation, pH and degree of acetylation. The source of chitosan and chitin influences their antimicrobial properties. Potential use of chitosan is very low due to their poor solubility in organic solvent [3]. Chitosan's amino and hydroxyl groups can undergo various modifications to adjust its physicochemical properties for specific applications. The chitosan derivatives exhibit strong antimicrobial activity against the Gram-negative bacteria viz. *E coli*, *Klebsiella*, Gram-positive bacteria viz. Staphylococcus aureus and *Staphylococcus mutans* as well as fungi viz. *Aspergillus* fumigatus and *Candida albicans* [12]. Chitosan derivative N-guanidinium chitosan acetate showed best antimicrobial activity against *E coli* ,*Pseudomonas aeruginosa*, *S aureus*, *Bacillus subtilis* and *Candida albicans* [13].

Chitosen and its derivatives have unique hypertensive properties. Hypertension causes the development of cardiovascular disease. Angiotensin-I converting enzyme contributes to the regulation of blood pressure by converting inactive angiotensin I in to its active form angiotensin II and this causes small blood vessels to narrow and blood pressure to rise. Inhibition of ACE activity may be beneficial in preventing hypertension. Chitosen derivatives-COS, in particular exhibited antihypertensive effects [14]. Their inhibitory effect on ACE is dependent on degree of deacetylation and molecular weight of the compound [15].

Common allergies occur as a result of interaction between an antigen and the antigen-specific immunoglobulin. However, asthma an allergic disease characterized by increased respiratory tract responsiveness. Vo et al. [16] showed that with three molecular weight ranges (1-3,3-5, and 5-10kDa) the lowest molecular weight attenuated allergic reactions by inhibiting degranulation and cytokinin production in mast cells. It has been reported that low molecular weight-COS has anti-inflammatory effects related to the regulation of Th2 and inflammatory, cytokines and therefore, and may be a promising candidate for the development of a potent therapeutic agent for the treatment of allergic asthma [17].

Obesity and diabetes are becoming a global burden on public health worldwide. Consumption of seafood plays a significant role in lowering obesity related health problem. Some of the ingredients in seafood are believed to have positive effect on the fight against obesity [18-20]. The level of Total Cholesterol (TC) and LDL-C in plasma and the triacylglycerol in the leaver and plasma are significantly reduced due to use of chitosan and its derivatives. Lowering the levels of lipids in the plasma results from the ability of chitosan to bind dietary lipids and the bile acids, and inhibit the activity of pancreatic lipase, thus reducing the absorption of intestinal fat in the gastrointestinal tract [21]. There are many studies which indicate that gain reduction in overweight is a factual phenomenon [22-24]. However, it has also been established that chitosan derivatives had only a minor effect on weight loss and therefore unlikely to be of clinical relevance [25].

Chitosan has an anti-cancer effect by limiting the growth of cancer cells [3]. The anti-tumor activity results from the potential stimulating effect on immune system [8] as well as inhibiting angiogenesis and apoptosis from DNA fragmentation [9]. Sayari et al. [25] extracted chitin from by-products of N norvegicus, and the chitosan was obtained by partial deacetylation of chitin. The biopolymer showed antiproliferative activity against HCT116 colon cancer cells.

Proteins and peptides

Bioactive molecules are collagen, gelatins and albumins, and their sources are marine fishes. These compounds are mainly used in meat industry and have anti-oxidant, and anti-hypertensive properties [26,27]. Other components under protein and peptides are gelatine and albumin which are available from marine fishes and are used to treat chronic atrophic gastritis. The third bioactive molecule in this category is albumin which are available from molluscs and crustaceans. Albumin is basically an anticoagulant having anti-oxidant properties [28-29].

Polysaccharides

Polysaccharide is a biological compound found in many species of marine algae and crabs and krill [30]. The marine-derived polysaccharides are safer than mammalian polysaccharides and therefore, more suitable for drug development, nutraceuticals and cosmetics (31 Simat 59). Marine-derived bioactive polysaccharides include carrageenan, fucans fucoidan, agar furcelleran, ascophyllan, laminarin, polyuronides, alginates, chitin and chitosan having a range of biological activities which include anti-tumor, anti-cancer, anti-coagulant, anti-virus, cardioprotective, anti-inflammatory, antiallergic. Anti-oxidant, anti-diabetic, anti-bacterial and protease inhibitor activities [5,30,31]. Carrageenan and gelatin, the gel forming agents, have anti-HIV activity and anti-coagulant properties [32]. Agar is also a gel forming agent and are found in red alga [33]. Fucans and fucoidan are used as nutraceuticals and are available from cell walls of brown alga; they have anti-coagulants, antiviral, anti-thrombotic, proliferative and anti-inflammatory properties [34] and the most important components are chitin, chitosans and derivatives. These are gelling agents and edible protective films. Available from shrimps, crab lobster, prawn and krills, chitin and its derivatives have anti-oxidant, antimicrobial, anti-hypertensive, anti-allergy and anti-inflammatory, anti-obesity and antidiabetic, and antitumor activities [3].

Fucoidan, a sulphated polysaccharide is found in brown macroalagae has an array of biological activities. Fucoidan extracts are generally used in foods and dietary supplements for human consumption in a dose up to 250mg/day. Fucanoids from brown macroalgae also have an inhibitory role in colony formation in human melanoma and colon cancer cells [35].

Alginate, a linear polysaccharide, is naturally present in the brown macroalgae cell wall. Alginate has diverse applications such as alginate fibre wound dressings, as dental impression materials and preventing gastric reflux [36]. Other uses of alginate are food protection, gelling, thickening, coating, emulsifying and stabilizing agents in food products [37,38].

Carrageenan is structural component of red macroalgae cell membrane and has various biological activities such as anti-thrombotic, anti-viral, anticancer and immunomodulatory [39,40]. Carrageenan is applied in drug delivery, bone and cartilage tissue regeneration and wound healing [41].

Ulvan is found in green macroalgae (Order Ulvales: Ulva and Enteromorpha sp) [39]. Main constituents of ulvan are sulphate, xylose, rhamnose, iduronic and glucuronic acids. Major biological activities of ulvan are antiviral, anticancer, antioxidant, immunomodulating and antihyperlipidemic. Ulvan controls cholesterol level by reducing total serum control Low Density Lipoprotein (LDL) cholesterol and triglycerides and elevate High Density Lipoprotein (HDL) cholesterol [42].

Pigments

The natural algal pigments synthesized by marine algae can be classified into three essential categories viz. carotenoids, chlorophylls and phycobiliproteins [41]. The stability of these compounds is dependent on their chemical structures, which are influenced by several factors such as oxygen, light, heat, air and pH [43]. The pigments are also characterized their photosynthetic roles [44]. Photosynthetic pigments have various pharmaceutical and health improving applications, such as their use in histochemistry, immunoassays, flow cytometry and cell imaging. The natural pigments are applied as food colourants, in nutraceuticals and cosmetic industries as they have antioxidant activity, antimicrobial, antidiabetic, anticarcinogenic, anti-inflammatory, anti-obesity and anticancer activities [3,45-47].

Phenolic compounds

Phenolics are aromatic compounds having one or more than one hydroxyl groups. A wide range of phenolic substances, including primary and secondary metabolites are found in plants which include phenols, phenylpropanoids ,flavonoids, benzoic acid derivatives, lignans, tannins, stilberns and lignins [48]. There are many environmental factors. such as salinity, UV radiation, temperature, and nutrient availability which influence the natural production of phenolic compound in marine organisms [3]. Phenolics found in marine macroalgae vary from simple phenolics to complex molecules such as phlorotannins. Phenolics from macroalgae from macroalgae have natural anti-allergic properties for allergy remission [49], as functional ingredient in pharmaceuticals and prevention of neurogenerative disease and cardiovascular disease [50,51], and as compounds that have antidiabetic effect [52]

Marine enzymes

This group include gastric proteases, pepsins, gastricins and chymosins. Available in various fish body viscera like Atlantic cod, carp, harp, seals and tuna etc. They are cold renneting milk and fresh feed digestion aid [49]. Major sources of serine, cysteine and proteases, and lipases and transglutaminase are crustaceans, molluscs, seal and various species of sea fishes [49,53].

Vitamins and minerals

This group includes fat- and water-soluble vitamins, iron, iodine manganese and zinc which are used in food pharma and nutraceutical industries. Vitamins and minerals perform many essential functions in the body [54].

Fatty acids

Marine macroalgae also contains other important molecule like fatty acids, proteins and vitamins Omega-3 fatty acids are mostly marine fish-derived have unique nutraceutical properties. These have numerous health benefits which include reduction risk of cardiovascular problems and amelioration of diseases such as arthritis and hypertension [55].

Conclusion

Marine organisms are becoming unique source of biologically active compounds and being used in food, functional food and food supplement. Polysaccharides, chitin, chitosan, gelatin, peptides, pigments, polyphenols, minerals and vitamins, polyunsaturated fatty acids have diverse biological activities related to human ailments. Many are food ingredients, food colouring, food supplements, food property enhancer, health promoting food for consumption. There is serious concern among people on the benefits of natural food supplements and ill effect of synthetic one.

There is a need to adopt eco-friendly technologies for extraction of active compounds. Cultivation of the raw material should be given proper attention and it should be cost effective. Nanotechnology is emerging as a potential technology in food, medicine and nutraceuticals. Nanofibers are being used to enhance the stability of food materials. Nanotechnology applications of marine-based nutraceuticals could be integrated with other food materials having probiotic properties. Proper clinical trials will be a necessity to discover and confirm the therapeutic effect of new molecules.

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