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Review

Marine bioactive compounds and health promoting perspectives; innovation pathways for drug discovery

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ABSTRACT

Background: Marine organisms are one of the most important sources of bioactive compounds for the food and pharmaceutical industries. Bioactive compounds can be isolated from various sources including marine plants, animals and microorganisms.

Scope and approach: Marine bioactive compounds exhibit significant and biological properties contributing to their nutraceutical and pharmaceutical potential and are also considered to be safer alternatives to some existing synthetic drugs. As such, some marine bioactive compounds are currently under investigation at an advanced stage of clinical trials with a few of them already being marketed as safer drugs.

Key findings and conclusions: Marine bioactive compounds that have been the most extensively studied include carbohydrates, pigments, polyphenols, peptides, proteins and essential fatty acids. These compounds have rheological properties, deeming them useful in the food industry, as well as various biological functions like anti-oxidant, anti-thrombotic, anti-coagulant, anti-inflammatory, anti-proliferative, anti-hypertensive, anti-diabetic and cardio-protection activities making them attractive nutraceuticals and pharmaceutical compounds. This review summarises current research on bioactive compounds from different marine sources and brings into focus the potential use of these compounds in the food industry and in drug discovery to treat and prevent various chronic diseases.

1. Background

1.1. Marine bioactive compounds

Marine flora and fauna are excellent sources of bioactive compounds with therapeutic benefits that represent a valuable source of new compounds. The biodiversity of the marine environment and its associated chemical diversity contribute to an almost unlimited resource of new bioactive compounds (Pihlanto-Leppälä, 2000). Bioactive compounds can be isolated from various sources including marine plants, animals, microorganisms and sponges with unique set of molecules (Rasmussen & Morrissey, 2007). Bioactive compounds extracted from these organisms are effective against different infectious and non-infectious diseases. Six hundred and fifty new marine compounds were isolated in 2003 from the marine environment (Kim & Wijesekara, 2010) highlighting the great potential of marine sources. Therefore, the following review presents current knowledge that demonstrates the suitability of marine bioactive compounds in drug discovery to treat and prevent various chronic diseases.

1.2. Marine bioactive molecules and the food industry

Numerous marine bioactive compounds are utilized in different food products at industrial scale. Marine products are rich in proteins containing both essential and non-essential amino acids, polysaccharides, polyunsaturated fatty acids (PUFAs), vitamins, minerals and many other nutrients (Venugopal, 2005). These compounds can be isolated from fish, shellfish, molluscs (including mussel, oyster, scallop, abalone, snail and conch), cephalopods (including squid, cuttlefish and octopus), crustaceans (including crayfish, crab, shrimp and lobster), echinoderms, seaweeds and microalgae (Kannan, Hettiarachchy, Marshall, Raghavan & Kristinsson, 2011). Marine organisms are able to provide different types of bioactive compounds at different quantities—an appealing

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attribute to the food industry.

Proteins from marine sources are used in food products because of their unique properties such as film foaming capacity and gel forming ability (Rasmussen & Morrissey, 2007). Marine gelatin is formed during the partial hydrolysis of collagen and is used as a food additive because of its gel forming ability, texture improvement, water holding capacity and food product stability (Rustad, 2003).

Marine polysaccharides are sourced from a variety of organisms and display several properties making them suitable for inclusion in food products, in particular marine polysaccharides are able to bind large amounts of water and disperse it in food products (Berna, Cirik, Turan, Tekogul & Edis, 2013). For example, agar can be used in confectionery industries because of high sugar content, bland taste and does not impart flavour in jellies, jams, fruit candies, puddings, and custards. Carrageenans are used to modify the textures of diverse food products through changes in water binding, foaming and emulsifying attributes. Textural modifications of food are influenced by the interactions of these polysaccharides with other food components (Yu et al., 2002). Other marine polysaccharides such as alginate, chitosan and fucoidan are also ideal raw materials for edible, biodegradable films because of their gel forming ability. Chitin, chitosan and their derivatives also have variety of food applications including use as antimicrobial agents, edible films, additives, nutraceuticals (e.g., increasing dietary fibre, reducing lipid absorption) and water purifiers (Fiszman & Salvador, 2003).

Marine pigments such as carotenoid and chlorophyll molecules are used as natural colorants and antioxidants in different food products (Schoefs, 2002). Beta-carotene can be extracted from Dunaliella salina, one of the most suitable sources producing up to 14% of beta-carotene of its dry weight (Metting, 1996). Moreover, Dharmaraj, Ashokkumar, and Dhevendaran (2009) confirmed the production of food grade carotenoids from Callyspongia diffusa, marine sponge. Beta-carotene is one of the leading food colorants in the world and has been applied to a range of food and beverage products to improve their appearance to consumers (Dufossé et al., 2005). Chlorophylls are also used as natural colorants in food and beverage industries. Furthermore, phycobiliproteins can be derived from marine blue–green and red algae, which also have potential as natural food colorants. Therefore, marine bioactive compounds have important functional properties that could be scaled up and economically favorable as ingredients for the food industry (Park, Jung, Nam, Shahidi, & Kim, 2001) Table 1.

An extensive array of various compounds are added into food products in order to produce desirable characteristics in finished products. Accordingly, marine bioactive compounds are capable of improving the texture, appearance, quality and stability of finished food products. Marine bioactive compounds also appear to be suitable and attractive to the food industry owing to their natural availability, relatively cost effective extraction methods and biological activities that can promote health and reduce the burden of various diseases.

2. Marine bioactive compounds and health benefits

The incidence of chronic diseases such as cancer, cardiovascular disease, diabetes and obesity is rapidly increasing (Nugent, 2008), as such there is a need for the development of new and safe therapeutics to meet the growing health needs of the global population. Marine organisms are valuable sources of bioactive compounds that can be used as food additives, nutraceuticals or pharmaceuticals. It has been reported that consumption of marine foods and marine bioactive compounds can reduce the burden of diseases (Lordan, Ross, & Stanton, 2011). Some of the major health effects and therapeutic uses of marine sources and their bioactive compounds are illustrated in the following sections Table 2.

2.1. Anti-oxidant activity

Food industries are working towards the development of anti-oxidants from natural sources that offer safer alternatives to many synthetic commercial anti-oxidants. Food deterioration occurs because of the oxidation of lipids and results in production of undesirable compounds leading to the spoilage of food commodities. Lipid oxidation by reactive oxygen species (ROS) like hydroxyl radicals, hydrogen peroxide and superoxide anions decrease the nutritional properties of lipid enriched food. In order to reduce the lipid peroxidation several synthetic anti-oxidants are used such as propyl gallate, butylated hydroxytoluene, butylated hydroxytoluene and *tert*-butylhydroquinone. The use of synthetic anti-oxidants are tightly regulated in some countries because of their health related issues (Je, Park, & Kim, 2005); for this reason, researchers are investigating natural anti-oxidants as safer alternatives with marine organisms providing many candidate bioactive compounds (Pena-Ramos & Xiong, 2001).

Aside from the role of ROS in the deterioration of food products, excessive ROS are also associated with various diseases such as neurodegenerative, inflammatory diseases and cancer (Cornish & Garbary, 2010). The reaction of ROS with biomolecules like proteins, membrane lipids and DNA results in cellular or tissue level injuries. Equilibrium between endogenous anti-oxidant systems and oxidant formation protects cellular biomolecules, however a disturbance in this balance can lead to oxidative stress. Therefore, anti-oxidants play a vital role in maintaining the cellular redox state and protecting the body against damage caused by ROS (Ngo, Wijesekara, Vo, Ta, & Kim, 2011).

Marine sourced bioactive compounds with anti-oxidant activity fall into several categories including proteins, peptides, carbohydrates, pigments and polyphenols. Examples from each category are discussed in the following sections.

1. Marine peptides and phycobiliproteins

The beneficial effects of marine bioactive peptides include scavenging ROS and preventing lipid peroxidation (Qian, Jung, Byun, & Kim, 2008). In the last few years, different studies have isolated, characterized and purified bioactive peptides from different marine sources with anti-oxidant potential. Some of the major marine sources are Pacific hake (Samaranayaka & Li-Chan, 2008), cod (Slizyte et al., 2009), hoki (Kim, Je, & Kim, 2007), mackerel (Wu, Chen, & Shiau, 2003), jumbo squid (Mendis, Rajapakse, Byun & Kim, 2005), Alaska pollack (Cho et al., 2008), blue mussel (Rajapakse, Jung, Mendis, Moon, & Kim, 2005a), conger eel (Ranathunga, Rajapakse, & Kim, 2006), oyster (Qian et al., 2008), scad (Thiansilakul, Benjakul, & Shahidi, 2007), yellow stripe trevally (Klompong et al., 2009), tuna (Je, Qian, Lee, Byun, & Kim, 2008), yellow fin sole (Jun, Park, Jung, & Kim, 2004), capelin (Amarowicz & Shahidi, 1997), and microalgae (Sheih, Wu, & Fang, 2009a).

Mendis, Rajapakse, Byun, and Kim (2005b) isolated bioactive peptides from jumbo squid and demonstrated inhibition of lipid peroxidation by these peptides using a linoleic acid model system. The anti-oxidant activity of the isolated peptides was found to be comparable to the synthetic anti-oxidant butylated hydroxytoluene. It was further deduced that anti-oxidant activity could be attributed to the presence of particular hydrophobic amino acids in the isolated peptides. In another study, one of the anti-oxidant peptides (Leu-Lys-Gln-Glu-Leu-Glu-Asp-Leu-Leu-Glu-Lys-Gln-Glu) isolated from oyster (*Crassostrea gigas*), showed higher anti-oxidant activity than the synthetic anti-oxidant α-tocopherol in