Health Benefits of Seaweeds Consumption

Subjects: Food Science & Technology

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Recent studies demonstrate the high nutritional value of seaweeds and the powerful properties that seaweeds' bioactive compounds provide. Species of class Phaeophyceae, phylum Rhodophyta and Chlorophyta possess unique compounds with several properties that are potential allies of our health, which make them valuable compounds to be involved in biotechnological applications.

Keywords: seaweeds ; bioactive compounds ; human health ; pharmaceutical application ; nutraceutical application

1. Introduction

Seaweeds are considered a nutrient-rich food as they are a good source of minerals, vitamins (A, B_1, B_2, B_9, B_{12}, C, D, E, and K), essential minerals (calcium, iron, iodine, magnesium, phosphorus, potassium, zinc, copper, manganese, selenium, and fluoride), dietary fibers [1][2][3][4], protein, essential amino acids and polyphenols, which exhibit antioxidant and anti-inflammatory properties [5]. Seaweeds possess a low lipid content, nonetheless enriched in polyunsaturated fatty acids. This characteristic makes them even more attractive, as they are a healthy, nutritive and low-caloric food [2]. Seaweeds were consumed as whole food since ancient times, and they still have great economic importance. *Saccharina* spp. with *Porphyra* spp. and *Undaria pinnatifida* (Phaeophyceae) are the three algae mainly consumed in Asian meals [6].

Seaweed bioactive compounds are also employed in biomedical and pharmaceutical industries as they possess antitumoral activity against some type of cancer cell lines, but they do not affect negatively healthy cells, as it happens with current antitumoral treatments [7][8]. Phycocolloids, which derive from brown and red algae, are used in the food industry (gelling agents), pharmaceuticals (dressings, coatings of medicaments) and biotechnology (culture medium, the Petri dishes). They are also found in cosmetics (body lotions, soaps, shampoos, toothpaste) [9]. Marine algae have been traditionally used in animal feed and in agriculture and production of biodiesel.

Seaweeds are classified as brown, red or green algae, and for each group are present diverse bioactive compounds with multiple properties which may be exploited for biotechnological applications. Phaeophyceae (brown algae) have been consumed as whole food for a long time in Asian countries; however, scientists have only recently gained an understanding of the reasons behind the positive effects that seaweed bioactive compounds have on our health. Brown algae possess fucoidans that are already available in the market as nutraceutical products, since they exhibit antibacterial [10], antiviral [11] anti-inflammatory, anticoagulant, and antithrombotic effects [12]. Rhodophyta (red algae) extracts are widely exploited in medical and pharmaceutical sectors, particularly carrageenans and agar. Agar is used in biomedicine as suspension component in drug solutions and in prescription products, but also as anticoagulant agents [13]. Carrageenans can be exploited for the production of antitumoral therapies, due to their antitumor immunity activation [7]. Chlorophyta (green algae) are rich in ulvan, a sulphate polysaccharide commonly used in biomedicine, cosmetic and pharmaceutical industries but also as emulsifiers, stabilizers, and thickeners in food products [14].

The human health benefits from seaweeds can be through direct and indirect way: through the consumption of the whole seaweed or the uptake by assumption of food supplement or natural drugs (direct health benefits) or by using seaweeds in agriculture as natural fertilizers, in order to have a nutrient soil and healthy cultivation without the presence of chemicals contained in traditional fertilizers. Thus, the use of seaweeds as biofertilizers will enhance the plants and soil conditions [15][16][17], giving positive effects to our health after agriculture products consumption (indirect health benefits).

2. Main Bioactive Compounds of Seaweeds

Seaweeds are rich in several bioactive compounds such as polyphenols, sterols, alkaloids, flavonoids, tannins, proteins with essential amino-acids, polyunsaturated fatty acids, etc. [13]. These bioactive compounds provide not only protection to seaweeds, but also a high nutritional value and several benefits for humans. For example, polysaccharides from seaweeds have a positive effect on intestinal tract, but contrary to fibres, they are free of calories [2]. Agar and

carrageenan, extracted from red algae, and alginates, extracted from brown algae, are commonly employed in food and pharmaceutical products as stabilizers [18].

Due to their beneficial properties, these biological compounds extracted from marine algae have been received attention from researchers. These compounds might be employed for creation of novel and functional food but also for pharmaceutical and biomedical applications [19].

3. The Health Benefits of Seaweed Bioactive Compounds

Seaweeds bioactive compounds are exploited in several biotechnological applications (Table 1). Due to their properties, these compounds can contribute to the development of biomedicine and modern pharmacy, in order to achieve new formulation based on components from natural origin. The consumption of seaweeds by food or trough natural drugs will contribute to the occurrence of a healthier lifestyle. Nutraceutical, biomedical and pharmaceutical applications that involve seaweeds' bioactive compounds are further showed.

Table 1. Main compounds of seaweeds involved in biotechnological applications.

Seaweed	Main Bioactive Compound	Property	Biotechnological Application	Reference
Phaeaophyceae				
Laminaria hyperborea *Ascophyllum nodosum* *Ecklonia radiata* *Durvillaea* sp. *Lessonia* sp. *Sargassum* sp. *Scytothalia dorycarpa* *Cystophora subfarcinata* *Sargassum linearifolium*	Alginate	Biodegradability, biocompatibility, non-toxic behaviour	Cosmetics, pharmaceutical and food industries as stabilizers	[18][20]
Macrocystis pyrifera	Alginate	Biodegradability, biocompatibility, non-toxic behaviour	Cosmetics as a thickening agent	[21]
	Phlorotannins	Antioxidant activity	Cosmetics for preventing skin aging	[22]

Seaweed	Main Bioactive Compound	Property	Biotechnological Application	Reference
Ecklonia cava	Phlorotannins	Anticancer, antioxidant, anti-inflammatory, antiviral activities and antihypertensive effects.	Pharmaceutical and nutraceutical industries	[23][24][25]
Eisenia arborea	Phlorotannins	Antiallergic effects	Pharmaceutical industry	[26]
Eisenia bicyclis	Phlorotannins	Antidiabetic, antioxidant, antitumor, anti-inflammatory, and anticancer activities	Pharmaceutical and medical industries	[27]
Ecklonia kurome				
Ecklonia stolonifera				
Pelvetia siliquosa				
Ishige okamurae				
Fucus vesiculosus	Phlorotannins	Anti-inflammatory and antioxidant properties	Cosmetics, to produce make-up and sunscreens	[28]
Fucus evanescens	Fucoidans	Anticoagulant activity	Potential substitute to heparin	[29][30]
Laminaria cichorioides				
		Rhodophyta		
Chondrus pinnulatus	λ-carrageenan and κ-carrageenan	High viscosity in drinks; antitumoral property	Food industry (production of drinks, e.g., milk and chocolate) and pharmaceutical industry	[7][31]
Chondrus armatus				
Chondrus yendoi				
Kappaphycus striatum	κ-carrageenan	Antitumoral activity against human nasopharynx carcinoma, human gastric carcinoma, and cervical cancer cell lines	Pharmaceutical industry	[32]

Seaweed	Main Bioactive Compound	Property	Biotechnological Application	Reference
Kappaphycus alvarezii	κ-carrageenan and agar	Antioxidant properties	Cosmetics and nutraceutical industry	[33][34]
Gracilaria edulis	Agar Phenolic, flavonoid, and alkaloid compounds	Antidiabetic, antioxidant, antimicrobial, anticoagulant, anti-inflammatory, and antitumoral activities; hypoglycaemic activity	Pharmaceutical industry	[35][36][37][38]
Laurencia catarinensis	Halogenated metabolites	Antitumoral activity	Pharmaceutical industry	[39]
Laurencia obtuse	Diterpene and sesquiterpene	Actions against different cancer cell lines (KB, HepG2 and MCF-7)	Pharmaceutical industry	[39]
Griffithsia sp.	Griffith (Protein)	Antiviral activity against MERS-CoV-2 virus and SARS-CoV-2 glycoprotein	Pharmaceutical industry	[40][41]
		Chlorophyta		
Caulerpa racemosa	Phenolic compounds and flavonoids	Antioxidant, scavenging, anti-proliferative activities of cancer line cells	Pharmaceutical and nutraceutical industries	[42][43]
Ulva lactuca	Ulvan	Antioxidant activity, antimicrobial and photocatalytic activities	Food industry (the whole body is used as salad) and industrial industry (production of biogas and biodiesel)	[44][43][45][46][47]
Ulva rigida	Ulvan	Antigenotoxic activity in human lymphocytes; hypoglycaemic effect in vivo experiment	Pharmaceutical industry	[48][49]
Ulva fasciata	Ulvan	Antioxidant and good mechanical properties; antiviral property	Industrial industry to develop bioplastics; pharmaceutical industry	[50][51]

4. Seaweeds Extracts in Industrial Applications

Seaweeds biological compounds are widely exploited in several industrial applications (Table 4). For example, these compounds have been explored for the production of biogas and biodiesel, which can be an alternative and efficient fuel to replace the use of fossil fuels. The SP ulvan extracted from the green seaweed possesses attractive physicochemical properties and biological activities, resulting in its applications in different innovative applications [52][53].

Ulvan extracted from *Ulva lactuca* (Chlorophyta) has been tested for production of biogas [45] and biodiesel [46]. Moreover, the optical, structural, thermal, and antioxidant properties make ulvan a potential contribute for new packaging material for food [54]. Ulvan from *Ulva fasciata* (Chlorophyta) was extracted and utilized to create edible films for food application. The

films presented good mechanical and physicochemical properties adapted for containing food. The water vapour permeability in the pack decreased, preserving better the food. Moreover, ulvan from *Ulva fasciata* presents strong antioxidant activity [50], making this polysaccharide a perfect candidate for the production of novel, sustainable and eco-friendly bioplastics.

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