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# Seaweeds: A Food for Our Future

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## Abstract

Seaweeds contain biologically active compounds with different therapeutic potentials. They have also found application in the food and pharmaceutical industries as sources of functional food ingredients, nutraceuticals, food supplements, food hydrocolloids and biotechnological products. Some algae are traditionally consumed as soups and vegetables, while others are used as a condiment and used in sauces. Much research has shown their antidiabetic, antihypertensive, antioxidant, anti-inflammatory, antimicrobial and immunomodulating action and they have been used as functional ingredients for the development of therapeutic agents to combat degenerative diseases. Algae are considered foods suitable for everyone for their low calorie content and the diversity of important nutrients such as proteins, essential amino acids, vitamins, minerals, both soluble and insoluble dietary fibers and bioactive compounds.

This review presents an overview of the properties and potentials algae applications highlighting that they are excellent candidates to be used as ingredients for health by the food industry.

## Keywords

Algae, Food, Chemical composition, Pharmacological activities, Biotechnology

## Introduction

Seaweeds have been present in aquatic environments for billions of years exerting an important oxygenating action for the ability to absorb $CO_2$ essential for chlorophyll photosynthesis, freeing up $O_2$ necessary for the survival of aquatic organisms. They have shown easy adaptability to the most hostile environments, simultaneously proving to be fundamental both from a nutritional, health and aesthetic point of view.

Seaweeds are classified by color and their habitat is also diversified, living some species fixed to the rocks, others to the rocky seabed, others float free at different depths depending on the radiation they use for photosynthesis: green seaweeds up to 10 m depth; blue-green up to 20 m; brown over 20 m; and red up to 15 m.

Numerous algal species are used as food for both humans and animals, especially in Asian countries, providing 90% of the total production [1, 2]. They represent a unique food being rich in minerals, proteins, vitamins, fibers, functional compounds [3]. Among the natural compounds derived from macroalgae, biometabolites have a wide range of biological activities: in fact, they are used as antibiotics, antivirals, antifoulings, anti-inflammatories, antimitotics, anti-hereditary, antibacterial and anti-cancer agents [4, 5].

The presence in high concentrations of iodine allows the use as a food supplement for its metabolism stimulating function [6]. Polysaccharides present as the main structural components of the cell wall are used in the cosmetic and pharmaceutical industry; they have the ability to form colloidal solutions when dispersed in water and exhibit various biological activities; they are used in preparations to prevent cellulite and obesity and also in cosmetics for the moisturizing action on the skin [7, 8].

Seaweeds also contain natural products with biocidal activity that can help eliminate parasite vectors in their larval stages or after complete metamorphosis in adults. They replace synthetic products, which are harmful to human health, showing they have a better rapidity of degradation and lower costs [9]. Many of them are useful in agriculture as fertilizer or as fodder for animals; in industry they are used as a renewable and ecological source from which to obtain fuel, in particular biodiesel [10].

## Microalgae

Microalgae are single-celled organisms visible only under a microscope, while they are received by the human eye when they join in large numbers to form colonies; they are widespread in both fresh and salt water ecosystems of which they form the basis of the food chain.

Some microalgae have been an important food since ancient times showing a high nutritional, restorative and pharmacological power: the Fucus seaweed was first described by Pliny the Elder in his Naturalis historia, calling it a "marine oak" for its similarity to the leaves of the oak and recommending it for the treatment of gout. Dioscoride Pedanio, a famous Greek doctor, in his treatise De Materia Medica, recommended its use against skin rashes, gastritis and intestinal and liver disorders; in 1862 the doctor Duchesne-Duparc used this alga to treat psoriasis, as described in the Traité pratique des dermatoses. and he realized that it was acting on the metabolism of fats, so he began to use it successfully in the treatment of obesity. The lake algae have been of great food importance: among the populations of South America, the Aztecs, had already discovered the restorative properties and were used by warriors; in Chad the Kanembu populations have exploited the natural blooms of Spirulina, Arthrospira platensis, from Lake Kossorom for food for centuries [11]; in Oregon the algal blooms of Klamath, Aphanizomenon flos-aquae, which spontaneously form in the lake, are collected and from them are obtained food supplements of wide consumption. Currently these algae are cultivated, collected, dried, reduced to powder and used both in preparation of daily food products, such as bread, pasta, biscuits or drinks, both as supplements to fill nutritional deficiencies improving the well-being of the organism, with a tonic and regenerating effect also on the immune system.

They contain proteins up to 60-70%; carbohydrates up to 30-40%; fats up to 10-20%, including omega 3, omega 6 polyunsaturated fatty acids, docosahexanoic acid; they contain minerals including Iodine, Iron, Calcium; Vitamins A, B1, B2, B12,; Carotenoids including β-carotene, luteolin, astaxanthin, chlorophyll and other molecules with high nutraceutical value.

Spirulina (*Arthrospira platensis)* and Chlorella (*Chlorella pyrenoidosa*), *Porphyridium cruentum and Rhodella maculata* have a high protein content including phycobiliproteins, water-soluble pigments that prevent the formation of free radicals; they are antioxidants, and are currently being studied for their anti-tumor properties. Among the amino acids, phenylalanine is present in rather high doses, known to reduce the sensation of hunger.

*Dunaliella bardawil* and *Haematococcus pluvialis* contain high concentrations of carotenoids, in particular α and β Carotene, Astaxanthin, useful as a food supplement and for protection from UV radiation. The Klamath seaweed, Aphanizomenon flos-aquae, contains substances with anti-inflammatory power, restorative and adjuvants for digestion and general well-being.

Microalgae are characterized by high reproductive capacity, even in adverse environmental conditions and even on soils deemed sterile: an interesting and potentially exploitable feature especially in areas of the world where the land is not fertile and where the use of nitrogen fertilizers is necessary.

The proliferative capacity of microalgae on organic substrates both in the presence and absence of light with the consequent production of various functional substances is of considerable interest in many industrial sectors:

*Aquaculture*, as food for mussels, crustaceans and larval stages of fish; astaxanthin a carotenoid present in them, for example, is used as a supplement for the breeding of salmonids, as a method to induce the desired coloring in fish, being naturally retained in the meat for its high stability [12].

*Nutraceutical*, to supplement a deficient diet being rich in substances with high nutritional power;

*Pharmaceutical*, for the isolation of bioactive molecules to treat diseases;

*Bioenergetic* for its high oil content and hydrogen production;

*Environmental* for their properties of reclaiming water, soils and polluted air.

The microalgae of the genus Porphyridium have been the subject of much attention for their commercial potential and their cultivation has been increased as a source for the production of B-phycoerythrin, long-chain polyunsaturated fatty acids and exopolysaccharides which are excellent raw material for foods, nutraceuticals and pharmaceuticals. During cultivation a problem to be addressed is to improve the yield in these substances.

In fact, it has been noted that many types of microalgae can change their biochemical composition or the accumulation of certain substances under stress conditions, related to strong light intensity or nitrogen limitation, with the possibility of directing the production of biochemical targets by changing the culture conditions [13-16]. Porphyridium sp. and Porphyridium cruentum are rich in sulphated polysaccharides which, due to their structure, are very interesting for industrial and pharmaceutical applications [17].

The microalgae of the genus Ostreopsis ovata, benthic dinoflagellates, which live on the surface of the red and brown macroalgae present on the seabed, have been the subject of growing scientific interest due to their implication in toxic events along the coasts that caused the deaths of organisms marine such as sea urchins, limpets, sea cucumbers and mussels and alarm in many seaside resorts for their effects on human health: diseases of the upper airways, conjunctival irritations, fever, muscle and joint pain. The toxicity of these microalgae is due to the ability to produce toxins, the palitoxins, so called from the name of the marine coelenterate (*Palythoa toxica*) from which they were isolated for the first time in 1971 in Hawaii. Palitoxins are among the most powerful non-peptide marine toxins and among the main causes of poisoning by fish products [18, 19]. The proliferation of microalgae is essentially linked to climatic factors and the characteristic signs of the phenomenon, observable with the naked eye, are the opalescence of water, the formation of foam on the surface, the presence of gelatinous material in suspension. Intoxication occurs both due to the consumption of molluscs, crustaceans or contaminated fish, and due to the inhalation of aerosols containing fragments of seaweed cells or toxins during bathing [20].

## Macroalgaes

### Phaeophyta-Brown algae

Macroalgae are large aquatic photosynthetic plants that come in different colors, including green, red, brown and blue, and in a variety of forms generally divided into three groups: Phaeophyta, Rhodophyta and Chlorophyta.

The Phaeophyta are brown algae, very complex organisms from an anatomical and morphological point of view, multicellular, exclusively of marine origin, which prefer cold and well-oxygenated waters. Brown algae have a great variety of shapes and sizes: from undifferentiated filamentous to the more complex one in which the thallus is well distinct in rhizoid, cauloid and phylloid. They contain chlorophyll a and c, b-carotene and large quantities of xanthophylls including fucoxanthin responsible for the brown coloring of these algae. The variety of pigments allows chlorophyll photosynthesis to be carried out at different depths in the oceans even where the sun's rays do not reach. The chloroplasts present inside the cells are made up of photosynthetic membranes with a wall formed by alginic acid in the outermost part and cellulose in the interior. The main reserve substance is a polysaccharide consisting of 20 glucose units, laminaran, which occupies the entire cytoplasm [21].

Brown algae produce large quantities of mucilage, alginates, useful for maintaining algal hydration; they are rich in carbon and iodine hydrates, so they have been widely used since the past for the treatment of endemic goiter. The most important property attributable to brown algae is related to the huge amount of iodine contained in them: they are in fact widely used by the herbal and pharmaceutical industry for the production of products against hypothyroidism and metabolism stimulants. Brown algae also have mild diuretic properties, as well as being decongestant in the urinary tract. The presence of alginates, mucilaginous substances, makes them useful for the formulation of herbal and pharmaceutical products that assist low-calorie diets, for their satiating properties and to reduce the absorption of fats and sugars. Alginic acid is used in the food industry as a thickener and stabilizer in the preparation of puddings, glazes, cream cheeses, meringues, in particular for the production of ice creams, as it prevents the formation of ice crystals even at low temperatures. The gelling ability depends on the content of guluronic acid endowed with affinity for divalent cations, in the presence of which the gelling process takes place with the formation of a thermostable gel. Alginates are active at low concentrations and do not alter the taste of food, they are low in calories and are also used for the preparation of dietetic products.

Alginic acid is also known for the chelating ability of its salts capable of eliminating heavy metals and many toxic substances from the body; the soluble sodium alginate, reacting with lead, forms insoluble chelates destined to be expelled from the body through the feces. This latter surprising property makes algae an indispensable food in the diet of all those who are forced to live in particularly contaminated environments. Alginic acid can be worked to obtain textile fibers, also used in surgery; the possibility of using alginate fibers to produce a special paper, useful in the field of the food industry, in food packaging has recently been studied; in the fight against fires by making products non-flammable; in lubricants, and paints; in agriculture as organic fertilizers [22, 23].

Some species of the brown algae of the genus Fucus (*F. vesiculosus, F. serratus and F. evanescens*) have been studied for the presence of a bioactive sulfurized polysaccharide, rich in fucose, Fucoidan, which can be used for a wide range of applications [24]. Fucoidan was extracted and identified for the first time by Kylin [25], who had called it "fucoidin" due to the presence of many sulphated fucose units that make up the main chain; subsequent investigations on the structure have highlighted the presence of small quantities of xylose, uronic acids, rhamnose and glucosamine [26]. It has also been discovered that sulfated polysaccharides exhibit antiproliferative and anticancer activities for carcinoma cell lines [27-29]; immunomodulating [30]; anticoagulants [31]; anti-inflammatory [32, 33]; other application of Fucoidan include use in nutraceuticals, as functional foods and as an additive in cosmetics [34, 35]. Many studies have shown that the properties of fucoidan are related to the content and the position of the sulphate group in the sugar chain, its molecular weight and the sugars present [36-38]. Recently the sulphated polysaccharides present in different species of marine algae have aroused great interest for applications such as biomaterials in the field of tissue engineering, regenerative medicine and administration of slow-release drugs not only for their characteristics of biocompatibility and biodegradability, but also for the their high availability and relatively low costs. Their use in these sectors concerns the production of films, microspheres, nano particles, hydrogels, etc. .. inside which these polysaccharides are able to perform different functions, such as binders, coatings, solid matrices, drug release modifiers, thickeners, stabilizers, disintegrants, solubilizers, emulsifiers, gelling agents [39, 40].

Sulphated polysaccharides have found applications in the production of nanoparticles and microparticles, since, being negatively charged, they can form complexes with opposite charge polyelectrolytes, thus allowing the inclusion of drugs in the polymer matrix at the molecular level. Subsequently, the drug is released from the polyelectrolyte complex by means of ion exchange mechanism with consequent breakdown and dissolution of the complex polymer [41, 42].

The most suitable polyelectrolyte proved to be chitosan and the fucoidan/chitosan nanoparticles ranged from 365 to 900 nm. with an optimal ratio between them of 1: 1 which allowed high yield and good stability, especially at the pH value 5 [43-45]. Fucoidan/chitosan nanoparticles were prepared and their activity against osteosarcoma was assessed [46]: experimental results showed that the nanoparticles were more effective than the native fucoidan which itself exhibits antitumor activity [47].

Fucoidan/chitosan nanoparticles were prepared by a gelation process and loaded with the base fibroblast growth factor (bFGF) a protein with a molecular mass of ~18 kDa, which is a powerful mitogen and regulates angiogenesis during growth and development. The bFGF by stimulating the proliferation of a wide variety of cells, such as mesenchymal, neuroectodermal and endothelial, it is effective in protecting neurons from all types of insults such as glutamate exotoxicity, ischemia, hypoglycaemia, nitrogen monoxide, free radicals [48, 49]. The nanoparticles thus prepared have been able to protect bFGF from enzyme degradation, allowing him to reach the blood brain barrier and act on nerve cells; they are free of toxicity while biocompatibility and biodegradability are high; the encapsulated materials moreover are released effectively and in not very long times. The production of hydrogels have been used for the administration of drugs for the therapy of ischemic diseases: after the subcutaneous injection in mice of an injectable chitosan/fucoidan microcomplex containing bFGF a very significant release of the protein has been noted with consequent neovascularization and formation of fibrous tissue [50, 51]. Fucoidan/chitosan interactions have also been used to create fucosfere for the treatment of skin burns: the wounds treated with fucosfere, have been characterized by an increase in epithelial thickness already after seven days due to the effect of fucoidan on the migration of fibroblasts, on the release of growth hormones and cytokines involved in re-epithelialization [52]. A nanoencapsulated form of the berberine-containing fucoidan/chitosan complex has been proposed in the oral treatment of intestinal dysbiosis for the antimicrobial and anti-inflammatory activity of this alkaloid showing a release efficiency of 40% [53].

Nano particles of chitosan-fucoidan were prepared by ionic gelation loaded with 85% of curcumin, a substance that exhibits anticancer activity, the application of which was very difficult by its low bioavailability, and it was noted that the release was sensitive to changes in pH reaching the optimum between pH 6-7. Various fucoidan-based nano particles loaded with curcumin have been developed in order to develop new effective anticancer therapies with systems that have demonstrated stability, biocompatibility as well as a significant amount of drug release, also reducing unwanted side effects [54, 55].

Nano chitosan/fucoidan particles have also been used for the release of antibiotics: gentamicin showed 99% release capacity in 72 hours [56]. Doxorubicin, an antibiotic and antineoplastic drug, was loaded onto nanoparticles with acetylated fucoidan which functioned as the carrier of the drug due to its immunomodulatory properties and the ability to produce anticancer cytokines. The complex was stable at pH 7.4 corresponding to that of the blood, while at a lower pH there was a release of more than 90% of the tumor agent: this dependent pH release profile makes the intravenous route the best route for administration as the release of a smaller amount of drug into the blood prevents side effects and increases its concentration in cancer cells [57]. Fucoidan biofilm and poly 2- hydroxyethyl methacrylate are used as biomaterial in ophthalmological therapy, especially in the pathology of dry eye and conjunctival irritations [58, 59].

## Rhodophyta red algae

Red algae owe their coloring to the presence of particular pigments known as phycoerythrins, alone or associated with blue pigments, the phycocyanins, which together with chlorophyll generate typically red or purple algae. They mainly contain cellulose, but in some species there are polysaccharides of considerable importance derived from galactose; the cell wall is rich in calcium carbonate so these algae are able to contribute to the formation of sedimentary rocks. The chemical composition is particularly varied: they contain sulfated polysaccharides such as agarans and carrageenans, galactans, proteins including phycobiliproteins, mycolectins and amino acids similar to mycosporins; minerals, polyphenols, lipid substances [60-62].

The protein content in red algae is higher than brown and green algae and represents 10-50% of dry weight, comparable or higher than some foods. Even if the presence of non-protein nitrogen increases the concentration of proteins and affects digestibility of the proteins themselves, These seaweeds have been proposed for the inclusion in diets of ruminants, poultry, rabbits and pigs [63-65]. In red algae predominates Lysine, an essential amino acid present in limited quantities in terrestrial vegetable protein foods such as corn, soy, rice and wheat, while Tryptophan, Methionine and Leucine are present in small concentrations. Particular attention deserves the bioactivity of these proteins: cardioprotective effects have been observed with reduction of blood pressure; antidiabetic activity; antioxidant and anti-anemic for increased iron absorption [66-68].

In red algae, the lipid component is very low, generally 1-5% but rich in ω-3 polyunsaturated fatty acids: α-linolenic acid (ALA), eicosapentaaenoic acid (EPA), docosahexaenoic acid (DHA), with a beneficial nutritional ratio ω6/ω3, very important because our body is unable to synthesize these acids which can only be taken in through food.

Significant differences in the fatty acid profiles between the various species can depend on the algae harvest period, climatic conditions and conservation; also the solvent used for the extraction influences the yield and composition of the lipid extracts [69, 70].

Polysaccharides are the main components of macroalgae and, as non-digestible substances, they are considered as dietary fiber and much attention has been paid to their health benefits. Agarose and Carrageenans are the most important polysaccharides present in red macroalgae and are known as galactans, because they consist of units of D-galactose and 3.6 anhydrogalactose.

Agarose is present in the cell wall of the algae of the order Gelidiales and Gracilariales and is a substance that is extracted in hot water and is used as a food additive also in Europe indicated as E406. The properties of agarose depend on several factors, the most important of which are the type of algae, the environmental conditions, the harvest time, the extraction process and storage. It is not digested due to the lack of specific enzymes, but is metabolized by intestinal bacteria into D-galactose. As a gelling and stabilizing agent it is used not only in the food and pharmaceutical sector, but also in the cosmetic industry and in analytical laboratories as a medium for microbiological cultures and for chromatographic applications.

In the food sector its gelling properties are used in the preservation of canned meat and fish; to improve the appearance of yogurths and cheeses; to clarify wine and fruit juices; to provide consistency to jams and puddings. In medicine, agar is commonly used as a laxative: in fact, passing undigested through the intestine, agar increases the fecal volume and promotes peristalsis; as an anticoagulant, in the treatment of wounds infected for its antibacterial action; in dentistry it is used as a thickener in toothpastes and for very precise intra-oral casts, being endowed with great elasticity. Agarose is biocompatible and has been used for the repair of neural tissues, cartilage and for the preparation of biomaterials: due to its low cell adhesiveness, agarose has been composed with degradable biomaterials for the release of drugs; it is used in bioengineering for biodegradable tissues and for wound healing [71].

Carrageenan is a gelatinous substance obtained mainly by boiling two red algae of the rocky coast of the North Atlantic (*Chondrus crispus* and *Gigartina mamitiosa*) and also from the genus Solieriacee typical of tropical waters and from the genus Gigartina present in the Mediterranean. It comes in the form of powder of different consistency, yellowish and odorless and consists essentially of sulfated polysaccharides esterified with calcium, potassium, sodium and magnesium salts which, by hydrolysis, give galactose and 3,6-anhydrogalactose, in different ratio, so as to differentiate three forms: carrageenan kappa, iota and lamda. These different compounds have similar properties, but different characteristics depending on the source from which they are extracted and the manufacturing process. In fact, the differences in the position of the sulphate and their proportion are responsible for the characteristic profiles of the gel: κ-carrageenan forms strong and rigid gels, ι-carrageenan forms soft gels and λ-carrageenan does not gel, but provides a solution for the high viscosity [72].

In the food industry, carrageenans are very useful for the preparation of dietetic foods such as syrups and jams with a low sugar content, but the most frequent and specific use of these substances is in the dairy sector. They are endowed with remarkable interaction capacities with proteins whereby complexes are formed between the sulphate esters of the polysaccharides and the ammonium ions of the proteins of milk , in the presence of calcium ions: the interaction with the milk casein is exploited in the production of cheeses and of milk and cocoa drinks [73].

In the pharmaceutical sector they are used as anticoagulant agents and as detoxifying agents of heavy metals, in particular cadmium, lead and strontium through an exchange mechanism [74]; the carrageenan hydrogel can also act as a scaffold for in vitro culture of cells derived from human skin for the purpose of preparing biodegradable tissues for the treatment of infected wounds [75]. Carrageenans are used in various drug delivery systems as matrices to control drug release, or as microcapsules and microspheres [76, 77].

Gelatin and microspheres of l- carrageenan have been used for the ophthalmic release of timolol maleate, an anti-glaucoma drug and the importance of the different polymer ratio has been highlighted: a higher content of gelatin in fact provides a faster release. λ-carrageenan microparticles have been used for ocular release of ciprofloxacin and also carrageenan microspheres to encapsulate allopurinol and local anesthetic agents, such as lidocaine hydrochloride, dibucaine hydrochloride and tetracaine hydrochloride [78, 79].

More recently, carrageenans have attracted the attention of the pharmaceutical industry, since have been shown to inhibit the attack of viruses such as human papillomavirus, dengue virus and herpes simplex virus [80-82].

## Chlorophyta green algae

The green algae known as Chlorophyta represent a heterogeneous group of single-celled and multi-cellular organisms, with more or less extended dimensions. Chlorophyceae are green to the eye due to the presence of chloroplasts, and the chlorophyll pigments contained therein are responsible for the photosynthesis process by transforming light energy into chemical energy. The typical coloring of green algae can take on different shades based on the variety of algae and, above all, on the basis of the composition of pigments: in fact, often times, chlorophyll is mixed with other red or yellow pigments, xanthophylls.

Sea lettuce, *Ulva lactuca* L., is a green alga belonging to the Ulvaceae family, typical of Mediterranean waters and cold temperate seas. The leaves, not very large and thin, are fixed to a helical peduncle. High up to 30 centimeters, translucent, of a bright bright green color, it is harvested in spring and autumn, in the seasons in which it has its best color which reflects the richness of nutrients. Its chemical composition is very varied and rich in substances with high food value. All eight essential amino acids are present in it; fatty acids with a moderate Omega 3 content; B vitamins, vitamin C, carotenoids; water-soluble starch polysaccharides and amylopectins; mineral salts, iron, especially calcium and magnesium present in balanced form and this causes the lactuca ulva to be considered an excellent natural supplement to preserve the muscles from cramps, while optimizing their functioning [83].

The raw aqueous extracts of *Ulva lactuca* were analyzed

with the chromatographic method highlighting the presence of antioxidant and antibacterial substances. Carotenoids, phenols and chlorophylls have been identified as positive indicators of antioxidant activity; moreover, these extracts showed great potential for antibacterial activity against six bacterial strains, *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*, *Micrococcus luteus, Klebsiella pneumoniae, Serralia marcescens*, with minimum inhibitory concentration values between 400 and 350 µg/ml. Particularly interesting is the *Staphylococcus aureus*, a common human bacterial pathogen that causes infections of the skin and soft tissues, resistant to antibiotics. It has been observed that the methanolic extracts of *Ulva lactuca* inhibit the development of staphylococci and this activity is dependent on the collection period of the macroalga. If a suitable time is chosen for the collection, in accordance with the moon phases, the activity is higher having reached the optimal concentration of the antimicrobial substances. The results obtained indicate that this alga represents a raw material, at very low cost, rich in natural dye with antioxidant and antibacterial properties and could be used as a natural preservative ingredient in food and in the pharmaceutical industry [84-86].

The benefits for the body are manifold, being indicated in case of prolonged stress, intense sporting activity, debilitating chronic diseases, insomnia, headache, in case of excessive sweating and in the prevention of osteoporosis. From some research it has been found an inhibitory activity against the protein aggregation of cholinesterase, beta-secretase and amyloid suggesting the use of this alga as an alternative source of antioxidants and natural compounds with neuroprotective potential for the management of Alzheimer's disease [87].

In the eastern regions, sea lettuce is consumed as food, both in the form of soups and salads, simply seasoned with oil, salt and vinegar; in Scotland it is used for soups and salads; it is eaten raw, as a salad also in Scandinavia, Denmark, Ireland, Indonesia. In Italy it is used for the preparation of fritters with seaweed, a typical Neapolitan dish.

*Ulvaria obscura* is a common seaweed that is found in temperate waters and in the Arctic Ocean, belonging to the Ulvaceae family, which is identified in the blooms of algae called "green tides". This is not a seaweed suitable for food use because of its ability to produce the dopamine neurotransmitter as a defense mechanism against herbivores: it has been experimentally observed that echinoderms, molluscs and arthropods reject it as food and this would represent a reason for the increase flowering in the higher productivity periods of the alga. It also represents a possible indicator of anthropogenic pollution as its growth rate depends on the increased availability of dissolved inorganic nitrose [88].

*Halimeda tuna* J. Ellis & Solander, known as sea prickly pear, is a green alga of the Halimedaceae family which presents itself as a series of roundish or reniform units, united so as to make them take on the appearance of a small fig of India. It is present throughout the Mediterranean Sea but also in the Atlantic, Pacific and Indian Oceans: typical of the coralligenous environment, it is possible to observe it even a few meters deep, in dimly lit environments such as the entrance to the caves. Its adaptation to dim light is aided by the fact that it contains two accessory photosynthetic pigments, the carotenoids siphonein and siphonxanthin, which absorb green, and also a and b chlorophyll [89, 90].

The development of this alga is much more abundant in summer than in winter. The total water content ranges from 77.27% to 82.70%, and the lowest value is observed during the autumn. The average dry matter content is around 21% and the raw fat content is 0.68% of dry matter, higher during the spring then decreases throughout the year. The protein content is rather low, 12% but it remains almost constant throughout the year. In summer there are also the highest values for the total organic substance, carbohydrates and calcium and magnesium ions. The higher concentration of nutrients observed during spring and summer could be explained considering that reaches the maximum growth in these seasons thanks to the optimal temperature and ecological factors such as the change in depth and position. The content of inorganic matter of Halimeda tuna reaches the maximum levels during the winter, a period which coincides with the slow growth of the plant and the reduction of production of organic matter. The water content also varies seasonally with the highest value reached in the spring and this figure agrees with the water content normally present in all marine macroalgae Chlorophyta; the values of Calcium and magnesium are quite high and increase in winter and spring when the organic mass of the alga increases [91, 92].

The genus Halimeda has been recognized as a source of antioxidant substances and several researches have been addressed to highlight the correlation between consumption of these algae and incidence of different pathologies. Experimental research in vitro and in vivo have shown the presence of antioxidant substances such as carotenoids, terpenes, polyphenols, florotannins, which by antagonizing the action of free radicals prevent the onset of some hepatologies such as atherosclerosis, diabetes, neurodegenerative diseases, carcinogenesis aging [93-95].

*Halimeda tuna* extracts obtained with different solvents have been tested against bacterial and fungal pathogens with a diffusion method. Chloroform, ethanol, methanol and water were the solvents used and the inhibition zones obtained were between 2 and 20 mm: the methanolic extracts showed a broad spectrum of antimicrobial activity compared to the others and the fungal strains were more sensitive to the extracts than bacterial strains: this increased activity of the metabolic extract may be due to the fact that the solvent proves to be more efficient in the extraction of the various components that have antimicrobial activity [96-98].

Halitunal, a terpene aldehyde consisting of a unique cyclopentadiene ring system [c] piranum, was isolated from the alga and identified by spectrophotometric method. This little-known aldehyde showed in vitro antiviral activity against the mouse coronavirus A59 [99].

## Conclusions

Algae have been identified as a source of natural compounds suitable for food, also showing many pharmacological properties.

For several years, algae have been used, for the peculiarity of their active principles, in the formulation of food and phytotherapy products; in the cosmetic field, their richness in mineral salts, including iodine at high concentrations, makes them capable of activating the physiological mechanisms in the deep layers of the tissues, promoting the drainage and firming of the tissues and being particularly useful for combating cellulite and skin relaxation. Many of them exhibit neuro-protective effects as inhibitors of cholinesterase, beta-secretase and amyloid protein aggregation and could be used as alternative sources of antioxidants and neuro-protective natural compounds for the management of Alzheimer's disease. Agar and carrageen hydrocolloids represent important products for different industrial applications. The integral use of this economically advantageous raw material is particularly interesting, subjecting the remaining biomass from the extraction processes of biologically active substances to a biorefinery process. Biomass is no longer considered waste material, but a productive resource of new substances favoring the economy of a process that could be adapted to the demand and needs of different sectors.

## Conflict of Interest

The author declares she has no conflicts of interest.

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