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Seaweeds are a Future Resource in Food as a Source of Raw Materials and Bio Functional Compounds

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ABSTRACT
Seaweeds contain biologically active compounds with diverse therapeutic potentials. Due to their presence in functional food ingredients, nutraceuticals, dietary supplements, food hydrocolloids, and biotechnology products, they have found application in both the food and pharmaceutical industries.
Some Seaweeds are traditionally consumed as soups and vegetables, while others are used as seasonings and use in sauces. Many researchers have shown anti-diabetic, anti-hypertensive, antioxidant, anti-inflammatory, antimicrobial and immune-modulating actions, employing them as functional ingredients for the development of therapeutic products for use in degenerative diseases. They are considered foods suitable for everyone because of their low calorie content and the presence of many important nutrients such as protein, essential amino acids, vitamins, minerals, dietary fibre, both soluble and insoluble, and bioactive compounds.
Keywords: Seaweeds, foods, chemical composition, pharmacological activities, biotechnology

I. INTRODUCTION

Seaweeds have been present in aquatic environments for billions of years exerting an important oxygenating action due to their ability to absorb CO2 essential for chlorophyll photosynthesis, releasing O2 necessary for the survival of aquatic organisms. They have demonstrated an easy adaptability to the most hostile environments, proving to be simultaneously essential both nutritionally, health-wise and aesthetically.

Seaweeds are classified according to color, and their habitats are also diverse: some species live attached to reefs, others to rocky bottoms, and others float free at different depths depending on the radiation they use for photosynthesis: green algae up to 10 meters deep; blue-green algae up to 20 meters; brown algae beyond 20 meters; and red algae up to 150 meters .

Numerous algal species are used as food for both humans and animals, especially in Asian countries, accounting for 90 percent of total production [1,2]. They represent a unique food by being rich in minerals, protein, vitamins, fibre and functional compounds [3]. Among the natural compounds derived from macro algae, bio metabolites possess a wide range of biological activities: in fact, they are used as antibiotics, antivirals, anti-fouling, anti-inflammatories, anti-micotics, anti- larvicides, anti- bacterials, and anti-carcinogens [4,5]. Due to the presence in high concentrations of iodine, whose main function is to stimulate metabolism, algae are also used as a supplement .

Polysaccharides present as the main structural components of the cell wall are used in have the ability to form colloidal solutions when dispersed in water and have various biological activities; they are used in preparations to combat cellulite and obesity and also in cosmetics for their moisturizing action on the skin [6,7].

Seaweeds also contain natural products with biocidal activity that can help eliminate parasite vectors in their larval stages or after complete metamorphosis into adults, replacing synthetic products, which are harmful to human health, proving, instead, to have better degradation speed and lower costs [8]. Many of them are useful in agriculture as fertilizer or animal fodder; in industry they are used as a renewable and environmentally friendly source from which to make fuel, particularly biodiesel [9].

II . MICROALGAE

Microalgae are single-celled organisms visible only under the microscope, while they are taken in by the human eye when they come together in large numbers to form colonies; they are widely spread in both freshwater and saltwater ecosystems of which they form the base of the food chain.

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Some microalgae have been an important food since ancient times showing a high nutritional, restorative and pharmacological power. The Fucus seaweed was described for the first time by Pliny the Elder in his Naturalis historia, calling it a "sea oak" for its resemblance to the leaves of the oak and advising it for the treatment of gout.

Dioscorides Pedanio, a famous Greek physician, in his treatise De Materia Medica, advised its use against rashes, gastritis and disorders of the intestine and liver; in 1862 the physician Duchesne-Duparc used this alga to treat psoriasis, as described in the "Traité pratique des dermatoses" and he noticed that it acted on fat metabolism, so he began to use it successfully in the treatment of obesity.

Lake seaweeds have been of great food importance: among the populations of South America. The Aztecs had already discovered their restorative properties and were used by warriors; in Chad the Kanembu populations have been exploiting for centuries the natural blooms of Spirulina, Arthrospira platensis, present in Lake Kossorom for food purposes; in Oregon the algal blooms of Klamath, Aphanizomenon flos-aquae, which form spontaneously in the lake, are collected and from them are obtained food supplements of wide consumption [10].

Currently these seaweeds are grown, harvested, dried, reduced to powder and used both in the preparation of daily food products, such as bread, pasta, biscuits or drinks, and as supplements to fill nutritional deficiencies improving the well-being of the body, with a tonic and regenerating effect also on the immune system.

These microalgae contain proteins up to 60-70% ; carbohydrates up to 30-40% ; fats up to 10-20% including polyunsaturated fatty acids, omega3, omega 6, docosahexaenoic acid; contain minerals including Iodine, Iron, Calcium; Vitamins: A, B1, B2, B12; Carotenoids including □ □ 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 studied for their anti-tumor properties. Among the amino acids there is phenylalanine in rather high doses, known to reduce the feeling of hunger (Fig1-4)

Fig.1 Spirulina (Arthrospira platensis)

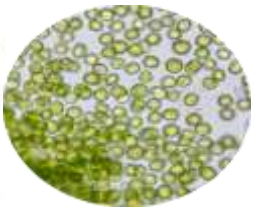

Fig .2 Chlorella (Chlorella pyrenoidos

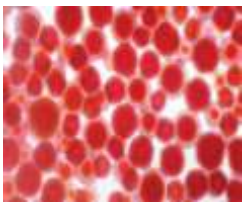

Fig.3Porphydium cruentum

Fig.4 Rhodella maculate

Dunaliella salina and Haematococcus pluvialis contain high concentrations of carotenoids, in particular □ □ □ and□ □□Carotene and Astaxanthin, useful as a food supplement and for protection from UV radiation. Klamath seaweed, Aphanizomenon flos-aquae contains substances with anti-inflammatory, restorative, coadjuvant power digestion and general well-being (Fig.5-7)

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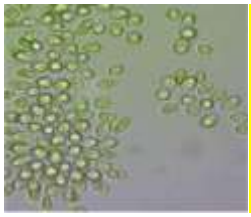
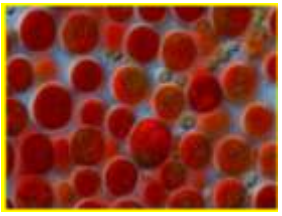

Fig.5 Dunaliella salina **Fig. 6 Haematococcus pluvialis**

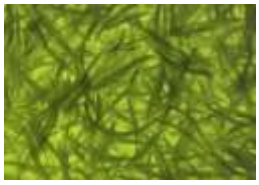
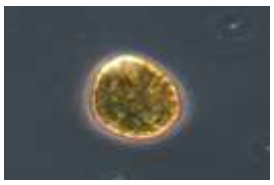

Fig.7 Aphanizomenon flos-aquae **Fig.8 Ostreopsis ovata**

Microalgae are characterized by high reproductive capacity, even in adverse environmental conditions and even on soils considered sterile: this is an interesting feature and potentially exploitable 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:

1.Aquaculture, as food for mussels, crustaceans and larval stages of fish. Astaxanthin, a carotenoid present in them, is used as a supplement for salmonid breeding, and represents a method to induce the desired coloration in fish, since it is naturally retained in meat due to its high stability [11] .
2. Nutraceutical, to supplement a deficient diet being these micro-algae rich in substances with high nutritional power.
3. Pharmaceutical, for the isolation of bioactive molecules to treat diseases.
4. Bioenergetic for high oil content and hydrogen production.
5. Environmental for their properties to reclaim water, soil and polluted air.

Microalgae of the genus Porphyridium have been the subject of much attention for their commercial potential and cultivation has been increased as a source for the production of B-phycoerythrin, long-chain polyunsaturated fatty acids and exopolysaccharides, representing excellent raw material for food, nutraceuticals and pharmaceuticals. During cultivation a problem to be faced is to improve the yield in these substances. 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 also by modifying the culture conditions [12- 15]

Porphyridium sp and Porphyridium cruentum are rich polyunsaturated fatty acids (PUFA), phycobilipro- teins and sulphated polysaccharides which, due to their structure, are very interesting for industrial and pharmaceutical applications[16**].**

The microalgae of the genus Ostreopsis ovata, belonging to the group of benthic dinoflagellates, commonly live in the warm waters of tropical seas on the surface of the red and brown macroalgae present on the seabed (Fig 8). Recently they have been the subject of a growing scientific interest because of their implication in toxic events along the coasts of Italy, causing the death of many marine organisms such as hedgehogs, limpets, sea cucumbers and mussels and alarm in numerous 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. Palicotoxins are among the most potent marine toxins of non-peptide nature and among the main causes of poisoning by fish products [17,18].The proliferation of microalgae is essentially linked to climatic factors and the

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characteristic signs of the phenomenon, observable with the naked eye, are water opalescence, foaming on the surface, presence of material of gelatinous consistency in suspension. Intoxication occurs either by consumption of contaminated shellfish, crustaceans or fish, or by inhalation of aerosols containing fragments of seaweed cells or toxins, during bathing [19].

III. MACROALGAE

III a PHAEOPHYTA - Brown algae

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

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 distinguished in rhizoid, cauloid and phylloid.

They contain chlorophyll a and c, □-carotene and large amounts of xanthophylls including fucoxanthin responsible for the brown coloration 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 consist 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 formed by 20 glucose units, laminaran, which occupies the entire cytoplasm [20].

Brown algae produce large quantities of mucilage, alginates, useful for maintaining algal hydration: they are rich in carbohydrates of carbon and iodine and since the past have been widely used in the treatment of endemic goiter. The most important property recognized to brown algae is related to the large 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 are stimulants of metabolism. Brown algae also have mild diuretic properties, as well as being decongestant of the urinary tract.

The presence of alginates, mucilaginous substances, makes them useful for the formulation of herbal and pharmaceutical products adjuvants of low-calorie diets, for their satiating properties and to reduce the absorption of fats and sugars. Alginic acid is also used in the food industry as a thickener and stabilizer in the preparation of puddings, glazes, cream cheeses, meringues; in particular, then, in the production of ice cream, as it prevents the formation of ice crystals even at low temperatures.

The gelling capacity depends on the content of guluronic acid, which together with mannuronic constitutes alginate, 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, are low-calorie, and are also used for the preparation of dietary products.

Alginic acid is also known for the chelating capacity of its salts that can eliminate heavy metals and many toxic substances from the body. Soluble sodium alginate, reacting with lead, forms insoluble chelates intended to be expelled from the body through the faeces, preventing intoxication that could be fatal. This last surprising property makes these algae an indispensable food in the diet of all those who are forced to live in particularly contaminated environments.

Alginic acid can be processed to obtain textile fibers, also used in surgery; Recently, the possibility of using alginate fibers to produce a special paper useful in the field of food industry in food packaging has been studied; as a cover in the fight against fires by making products non-flammable; in lubricants, and paints; in agriculture as organic fertilizers [21,22]

Some species of brown algae of the genus Fucus (F.vesiculosus, F.serratus and F. evanescens) have been studied for the presence of a bioactive sulphur polysaccharide, rich in fucose, Fucoidan, which can be used in a wide range of applications [23].

Fucoidan was extracted and identified for the first time by Kylin [24], who had called it "fucoidin".for the presence of many units of sulfated fucose that constitute the main chain; subsequent investigations on the structure have highlighted the presence of small amounts of xylose, uronic acids, rhamnose and glucosamine [25].

Sulfate polysaccharides have also been found to exhibit antiproliferative and antitumor activities for carcinoma cell lines [26,27]; are

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immunomodulatory [28]; anticoagulants [29]; anti-inflammatories [30,31]

Other applications of Fucoidan include use in nutraceuticals, as functional foods, and as an additive in cosmetics [32,33].

Many studies have shown that the properties of Fucoidan are related to the content and position of the sulfate group in the sugar chain, its molecular weight and the sugars present.[34-36].

Recently, sulphated polysaccharides present in several species of marine algae have aroused great interest in applications such as biomaterials in the field of tissue engineering, regenerative medicine and slow-release drug administration not only for their biocompatibility and biodegradability characteristics, but also for their high availability at relatively low costs. Their use in these sectors concerns the production of films, microspheres, nano particles, hydrogels, etc ... within 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 [37,38].

Sulfated polysaccharides have found applications in the production of nanoparticles and microparticles, since, being negatively charged, they can form complexes with opposite-charged polyelectrolytes, thereby allowing the inclusion of drugs in the polymer matrix at the molecular level. Subsequently, the drug is released from the polyelectrolyte complex by ion exchange mechanism resulting in breakdown and dissolution of the complex polymer [39,40].

The most suitable polyelectrolyte turned out to be chitosan, and fucoidane/chitosan nanoparticles ranged from 365 to 900 nm. with an optimal ratio between them of 1: 1, which allowed a high yield and good stability, especially at the pH value 5 [41-43].

Fucoidane/chitosan nanoparticles were prepared and their activity against osteosarcoma was evaluated [44]: experimental results showed that nanoparticles were more effective than native fucoidan even if it itself has antitumor activity [45].

Studies have shown the action of fucoidan/ chitosan nanoparticles prepared by a gelation process and loaded with basic fibroblast growth factor (bFGF), a protein with a molecular mass of ~18 kDa, which is a potent mitogen and regulates angiogenesis during cell growth and development. By stimulating the proliferation of a wide variety of cells, such as mesenchymal, neuro-ectodermal and endothelial, it is effective in protecting neurons from all kinds of insults such as: glutamate exotoxicity, ischemia, hypoglycemia, nitric oxide, free radicals [46,47]. The nanoparticles thus prepared were able to protect bFGF from the degradation of enzymes, allowing it to reach the blood-brain barrier and act on nerve cells. They are free of toxicity while biocompatibility and biodegradability are high; encapsulated materials are released effectively and in a short time.

Hydrogel production was used for the administration of drugs for the therapy of ischemic diseases: after subcutaneous injection into mice of an injectable chitosan/fucoidan microcomplex containing bFGF, a very significant release of the protein was noted resulting in neovascularization and formation of new fibrous tissue [48,49].

Fucoidane/chitosan interactions have also been used to create fucospheres for the treatment of skin burns: wounds treated with fucosphers have been characterized by an increase in epithelial thickness already after seven days due to the effect of fucoidan on fibroblast migration, on the release of growth hormones and cytokines involved in re-epithelialization [50].

Nano-encapsulated form of the fucoidane/ chitosan complex containing berberine 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% [51].

Several chitosan/fucoidan nanoparticles were prepared by ion freezing and loaded with 85% curcumin, a substance with antitumor activity, the application of which was made difficult by its low bioavailability. In this case it was noted that the release was sensitive to pH variations reaching the optimum between pH 6-7 and only with this precaution it was possible to realize new effective anticancer therapies with systems that have demonstrated stability, biocompatibility as well as a considerable amount of drug release, also reducing unwanted side effects [52,53].

Chitosan/fucoidan nanoparticles have also been employed for antibiotic delivery: gentamicin showed a 99% release capacity in 72 hours [54]; doxorubicin, an antibiotic and antineoplastic drug, due to its immunomodulatory properties and ability to produce antitumor cytokines, was loaded onto nanoparticles with acetylated fucoidan, which functioned as a carrier of the drug. The complex was stable at Ph 7.4 corresponding to that of the blood, while at lower pH there was a release of more than 90% of the

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tumor agent. This pH-dependent release profile makes the intravenous route the best for administration, as releasing less drug into the blood prevents side effects and increases its concentration in cancer cells [55]

Fucoidan/poly 2-hydroxyethyl-methacrylate biofilms are also used as a biomaterial in ophthalmological therapy, especially in the pathology of dry eye and conjunctival irritations [56,57].

III b RHODOPHYTA -Red algae

Red algae owe their color to the presence of particular pigments known as phycoerythrins, alone or associated with blue pigments; phycocyanins, which together with chlorophyll generate typically red or purple algae. (Fig 9,10).

Fig .9 Gracilaria verrucosa

Fig.10 Gelidium cartilagineus

They contain mainly 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 sulphate polysaccharides known as agaranes, carrageenan, galactans; proteins including phycobiliproteins, mycolectins and mycosporin-like amino acids; minerals, polyphenols, lipid substances [58-60]. .

The protein content in red algae is higher than in brown and green algae and accounts for 10-50% dry weight, comparable or higher than in some foods. Although the presence of non-protein nitrogen increases protein concentration and affects protein digestibility, they have been proposed for inclusion in the diets of ruminants, poultry, rabbits and pigs [61-63].

In red algae, lysine predominates, an essential amino acid present in limited quantities in terrestrial plant 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 with blood pressure reduction have been observed; antidiabetic activity; antioxidant and antianemic for increased iron absorption [64-66].

In red algae the lipid component is very low generally 1-5%, but rich in polyunsaturated fatty acids of the ω-3 type: α-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosahexae-noic acid (DHA), with a beneficial nutritional ratio ω6 / ω3, very important for our body that is not able to synthesize these acids, but can only take them through food.

Significant differences in fatty acid profiles between species may depend on the period of algae harvest, climatic conditions, conservation; the solvent used for extraction also influences the yield and composition of lipid extracts.[67,68].

Polysaccharides are the main components of red macroalgae and, as non-digestible substances, are considered dietary fibres and are recognized as being of great importance for the benefits they bring to the health of the organism.

Agarose and Carragenani are the most important polysaccharides present in red macroalgae and are known as galactans, because they consist of D-galactose and 3,6-anhydrolactose units.

Agarose is present in the cell wall of 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 referred to as E406. The properties of agarose depend on several factors among which the most important are the type of algae, environmental conditions, harvesting time, 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 means for microbiological cultures and chromatographic applications.

In the food sector its gelling properties are used in the preservation of canned meat and fish; to improve the appearance of yogurt and cheese; to

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clarify wine and fruit juices; to provide texture to jams and puddings.

Agarose is biocompatible and has been used in the field of tissue engineering for the repair of neural tissues, cartilage and for the preparation of biomaterials. Due to its low cellular adhesiveness, agarose has been composed with degradable biomaterials for drug release; is used in bioengineering for biodegradable tissue production and wound healing [69].

Agar is a polysaccharide used as a natural gelling agent and is obtained by processing red algae belonging to different genera, including Gelidium, Gracilaria, Gelidiella... Production can take place both industrially and traditionally. Traditional methods include techniques aimed at whitening and drying algae, so as to reduce their strong scent and intense flavor.

The algae after harvesting are dried in direct sunlight, a process that can take months, then they are boiled in vinegar. When the algae fibers have softened, they are pressed to obtain a homogeneous liquid, which is spread on large frames to obtain the consistency of a gelatin from which bars are subsequently obtained that are subjected to successive heating and cooling cycles and finally reduced to powder or flakes ready for use [70].

Agar has two different constituents: agarose and agaropectine. Agarose is a neutral linear polysaccharide composed of three units of β-d-galactose and four units of 3,6-anhydrous-α-l-galactose; Agaropectine is an acid polysaccharide containing sulfate groups, pyruvic acid and D-glucuronic acid conjugated with agarobiose.

The properties of agar depend on the species and environmental characteristics of the harvesting or cultivation area, such as season, life cycle, geographical features; The various extraction processes, post-harvest storage and post-extraction storage also have an influence. The quality of agar is determined by the type, degree of substitution of sulfate groups, molecular weight, chemical composition (pyruvate, methoxyl and sulfate) and physical properties (gel strength, gel syneresis, viscosity, gelling and melting temperatures) that determine its cost [71].

Agar is a food additive generally recognized as safe (GRAS) in the United States and an approved food additive in Europe. Agar cannot be digested in the gastrointestinal tract because humans lack the enzymes α/β-agarase, but it can be metabolized by gut bacteria into d-galactose [72]. Agar is used as a gelling and stabilizing agent and as a cryoprotector in the pharmaceutical, cosmetic and food industries; with a high degree of purity has also been used in microbiological soils and chromatographic techniques [73].

In medicine, agar is commonly used as a laxative: in fact, passing undigested through the intestine, agar increases fecal volume and promotes peristalsis, It is used as an anticoagulant, in the treatment of infected wounds for its antibacterial action; in dentistry, in the past, it was used as a thickener in toothpastes and to build intra-oral casts of high precision, being endowed with great elasticity [74].

Carrageenan is a gelatinous substance obtained mainly by boiling two red algae from the rocky coast of the North Atlantic (Chondrus crispus and Gigartina mamitiosa). It is also extracted from algae of the genus Solieriacee present in tropical waters and from the genus Gigartina present in the Mediterranean. It comes in the form of powder of different consistency, yellowish and odorless in color and consists essentially of sulphate polysaccharides esterified with calcium, potassium, sodium and magnesium salts which, by hydrolysis, give galactose and 3,6-anidoplactose, in different ratios, so as to differentiate three forms: carrageenan kappa, iota, lamda. These different compounds have similar properties, but different characteristics depending on the source from which they are extracted and the processing process. In fact, the differences in the position of the sulfate, and their proportional ratio are responsible for the characteristic profiles for the gel: κ-carrageenan forms strong and rigid gels, ι-carrageenan forms soft gels, and λ-carrageenan does not gel, but provides a high viscosity solution [75].

In the food industry, carrageenans are very useful for the preparation of dietary foods such as syrups and jams with low sugar content, but the most frequent and specific use of these substances is in the dairy sector. They are endowed with remarkable capacities of interaction with proteins, so complexes are formed between the sulphate esters of polysaccharides and the ammonium ions of proteins, in the presence of calcium ions: the interaction with milk casein is exploited in the production of cheeses and milk and cocoa drinks [76].

In the pharmaceutical sector, carrageenans are used as anticoagulant agents and as detoxifying agents of heavy metals, in particular cadmium, lead and strontium through an exchange mechanism [77]. Carrageenan hydrogel can also act as a scaffold for the in vitro culture of cells derived

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from human skin for the purpose of preparing biodegradable tissues for the treatment of infected wounds [78]. Carrageenans are used in different drug delivery systems as matrices to control drug release, or as microcapsules and microspheres [79,80].

Microspheres of gelatin and lamda-carrageenan have been used for the ophthalmic release of timolol maleate, an anti-glaucoma drug of which the importance of the different polymeric ratio has been highlighted: a higher gelatin content than carrageenan provides faster release. λ-carrageenan microparticles have been used for ocular release of ciprofloxacin, while carrageenan microspheres are used to encapsulate allopurinol and local anesthetic agents, such as lidocaine hydrochloride, dibucaine hydrochloride and tetracaine hydrochloride [81,82].

More recently, carrageenans have attracted the attention of the pharmaceutical industry, as carrageenan has been shown to inhibit the attachment of viruses such as human papillomavirus, dengue virus, and herpes simplex virus [83-85].

III c CHLOROPHYTA - Green algae

Green algae, known as Chlorophyta, represent a heterogeneous group of unicellular and multicellular organisms, with more or less extensive dimensions. The chlorophytes are green to the eye due to the presence of chloroplasts and the chlorophyll pigments contained therein are responsible for the process of photosynthesis by transforming light energy into chemical energy. The typical color of green algae can take on different shades depending on the variety of algae and, above all, according to the composition of pigments: often, in fact, chlorophyll is mixed with other red or yellow pigments, xanthophylls.

Green algae contain a higher protein concentration than other algae and therefore they are the subject of greater attention by researchers to use them in food, especially as protein source supplements. The quality of proteins can vary greatly, depending on the digestibility and availability of essential amino acids: compared to animal proteins they are deficient in some essential amino acids and more difficult to digest due to the presence of a high concentration of insoluble polysaccharides, but do not contain high levels of saturated fatty acids and cholesterol which are the main cause of the development of cardiovascular diseases and diabetes.

Lectins and phycobiliproteins are two families of bioactive algal proteins that have been exploited for several industrial applications. Lectins are glycoproteins known for their aggregation and high carbohydrate-binding specificity and are involved in several biological processes, including host-pathogen interactions, cell-to-cell communication, induction of apoptosis, tumor metastases and antiviral activities.

Phycobiliproteins are water-soluble proteins with an important role in photosynthesis, being capable of capturing large quantities of light energy, highlighting different color and absorption characteristics. Due to this characteristic they are used in the medical field in fluorescent labeling, flow cytometry, fluorescence microscopy and fluorescent immunohistochemistry; in the food sector as natural colorants for chewing gum, popsicles, sweets, drinks; in cosmetic products, such as lipstick and eyeliner [86-88].

The high protein content of algae may also be beneficial for use as animal feed, including aquaculture, farm animals and companion animals.

Sea lettuce, Ulva lactuca L., is a green algae belonging to the Ulvaceae family, typical of Mediterranean waters and cold temperate seas (Fig 11).

Fig.11 Ulva lactuca

Fig. 12 Ulvaria obscura

The leaves are not very large and thin are fixed to a helical peduncle; It can reach up to 30 cm in height, translucent, of a bright green color, it is harvested in spring and autumn, in the seasons when it presents its best color that reflects the richness of nutrients.

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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 fair content of ω3 ; B vitamins, vitamin C, carotenoids; water-soluble amylaceous and amylopectin polysaccharides; mineral salts, iron and in particular calcium and magnesium present in a balanced form.

Ulva lactuca is considered an excellent natural supplement suitable for preventing muscle pain caused by cramps, while optimizing its functioning [89].

In the raw aqueous extracts of Ulva lactuca chromatographically analyzed, the presence of antioxidant and antibacterial substances has been highlighted: carotenoids, phenols and chlorophylls as positive indices of antioxidant activity; they also showed great potential for antibacterial activity against six 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 concerns Staphylococcus aureus, a common human bacterial pathogen, which causes infections of the skin and soft tissues, resistant to antibiotics. It has been observed that methanolic extracts of Ulva lactuca inhibit the development of staphylococci and this activity is dependent on the harvesting period of the macroalgae.

If a suitable time is chosen for the collection, in accordance with the phases of the moon, the activity is higher, having reached the optimal concentration of 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 that could be used as a natural ingredient and preservative in food and in the pharmaceutical industry. [90-92].

The benefits for the body are manifold being indicated in case of prolonged stress, intense sports activity, debilitating chronic diseases, insomnia, headaches, in case of excessive sweating and in the prevention of osteoporosis.

Some research has revealed an inhibitory activity against the protein aggregation of cholinesterase, beta-secretase and beta-amyloid suggesting the use of this alga as an alternative source of antioxidants and natural compounds with neuroprotective potentials for the management of Alzheimer's disease [93,94].

Alzheimer's disease is a neurological condition that mainly affects elderly individuals and is characterized by cholinergic dysfunction, cognitive impairment, memory loss, neuronal death and behavioral disorders. The pathological mechanisms involved in the development of Alzheimer's disease are associated with cholinergic deficiency, beta-amyloid aggregation of tau phosphorylation, neuroinflammation and oxidative damage to neurons. Natural products of marine plants and organisms have been identified as important sources of bioactive compounds with neuroprotective potentials and fewer adverse effects than synthetic agents: florotannines, carotenoids, sterols, fucoidans and polyunsaturated fatty acids have shown strong neuroprotective potentials in several experimental models

In the eastern regions, sea lettuce is consumed as food, both in the form of soups and salad, 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, Indonessia. In Italy it is used for the preparation of seaweed pancakes, a typical Neapolitan dish.

Ulvaria obscura is a common seaweed found in temperate waters and in the Arctic Ocean, belonging to the Ulvaceae family, which is identified in the algal blooms known as "green tides" (Fig 12).

This is not an alga suitable for food use because of its ability to produce dopamine, a neurotransmitter, used as a defense mechanism against herbivores: experimentally it has been observed that echinoderms, molluscs and arthropods are not attracted to this alga for food purposes and this would represent a reason for the increase in flowering in periods of greater productivity of the alga. It also represents a possible indicator of anthropogenic pollution since its growth rate depends on the increased availability of dissolved inorganic nitrogen [95].

Halimeda tuna (Ellis J. & Solander,) known as sea prickly pear, is a green alga of the Halimedaceae family which looks like a series of roundish or reniform units, united so as to make them assume the appearance of a small prickly pear, fixed to the rocky substratum with thin rhizoids (Fig.13). It is present throughout the Mediterranean Sea and also in the Atlantic, Pacific and Indian Oceans: typical of the coralligenous environment, it is possible to observe it even at a depth of a few meters, in poorly lit environments such as the entrance to the caves. Its adaptation to

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dim light depends on the fact that it contains two accessory photosynthetic pigments, the carotenoids siphonein and siphonaxanthin, which absorb the green pigment, also chlorophyll a and chlorophyll b [96,97].

Fig .13 Halimeda tuna

Fig.14 Caulerpa racemosa

The development of this alga is much more abundant in summer than in winter: the total water content varies from 77.27% to 82.70%, and the lowest value is observed during autumn. The average dry matter content is around 21% and consists of 12% protein substances and 0.68% crude fats, with variable fluctuations throughout the year. In summer, the highest values are also recorded for total organic matter, carbohydrates, calcium and magnesium ions. The greatest concentration of nutrients, observed during spring and summer,

It could be explained in relation to the increased growth during these seasons, favored both by the optimal temperature and by ecological factors such as the change in depth and position.

The inorganic matter content of this alga reaches maximum levels during the winter, a period that coincides with the slowed growth of the plant and the reduction of organic matter production. The water content also varies seasonally with the highest value reached in spring and this figure agrees with the water content normally present in all Chlorophyta marine macroalgae [98,99].

The genus Halimeda has been recognized as a source of antioxidant substances and several researches have been directed to highlight the correlation between consumption of these algae and incidence of different diseases.

In vitro and in vivo experimental research has highlighted the presence of antioxidant substances such as carotenoids, terpenes, polyphenols, florotannins, which antagonize the action of free radicals and prevent the onset of certain diseases such as atherosclerosis, diabetes, neurodegenerative diseases, carcinogenesis, aging [100-102].

Halimeda tuna extracts obtained with different solvents were tested against bacterial and fungal pathogens by a diffusion method. Chloroform, ethanol, methanol and water were the solvents used and the inhibition zones obtained were between 2 and 20 mm: methanolic extracts showed a wide spectrum of antimicrobial activity compared to other solvents and fungal strains were more sensitive to extracts than bacterial strains.

This high activity of the methanolic extract has been considered as a greater extraction capacity of the solvent, which proves to be more efficient in the extraction of the different components that have antifungal activity 103-105].

Halitunal, a terpene aldehyde consisting of a unique cyclopentadiene [c] pyrane ring system, was isolated from the algae and identified by spectrophotometric means. This little-known aldehyde showed in vitro antiviral activity against mouse A59 coronavirus [106].

Caulerpa racemosa is a green algae that grows mainly in tropical regions, although some varieties can be found in subtropical regions.

In Southeast Asian countries, such as Indonesia, the Philippines and Malaysia, it is usually served raw as a salad or cooked vegetable. It has been noted that the cultivated species contains the necessary composition of carbohydrates, proteins, low lipid content combined with essential amino acids, mineral content and polyunsaturated acids, making it a potential candidate as an alternative source of functional food [107,108].

The ethanolic extracts of Caulerpa racemosa have shown promising antioxidant, reducing and antidiabetic activities so as to promote the potential use of it, in culture, as a functional food with therapeutic applications beneficial to human health.

IV. CONCLUSIONS

Seaweeds have been identified as a source of natural compounds suitable for food and also showing many pharmacological properties. Some species of macro algae are consumed as part of a basic diet because they are rich in functionally active compounds and several years are used, due

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to the peculiarity of their active ingredients, in the formulation of of food and herbal products.

In the cosmetic field, their richness in mineral salts, including iodine at high concentrations, makes them able to activate the physiological mechanisms in the deep layers of the tissues, favoring the drainage and firming of them, resulting useful to combat cellulite and sagging skin.

Much attention has been paid to marine macroalgae for the development of new drugs, nutraceuticals and food supplements having been experimentally ascertained their beneficial effects as antioxidant, antitumor, antidiabetic, anti-hypertensives, and antibacterial agents. Evidence has shown that compounds derived from macroalgae are able to improve learning and memory function in neurodegenerative conditions.

Many of them exhibit neuroprotective effects as inhibitors of cholinesterase protein aggregation, beta-secretase and amyloid and could be used as alternative sources of natural antioxidant compound alternatives for the management of Alzheimer's disease.

The hydrocolloids agar and carrageenan represent important products for different industrial applications.

Currently of great interest is the integral use of this raw material, economically advantageous, subjecting the biomass, obtained as waste from the extraction processes of biologically active substances, to a biorefinery process. Biomass is no longer considered useless material, but represents a productive resource of new substances, favoring the economy of a process that could be adapted to the demand and needs of different sectors.

Edible seaweeds are a rich and sustainable source of macronutrients, especially dietary fiber, and micronutrients, but continuous monitoring is necessary for food safety to avoid the intake of excessive amounts of iodine, heavy metals, toxic substances and other pollutants that could harm health.

Seaweeds certainly represent food safety for the future, but it is also necessary to guarantee health safety by increasing research, monitoring the presence of pollutants in the aquatic system, having legislation attentive to the possibilities of selling altered products with increased monitoring and complete labelling of products from seaweeds.

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