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A Comprehensive Review of Medicinal Algae

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Abstract

Algae are a diverse group of photosynthetic organisms. Besides oxygen production, they contain various compounds that give them nutritional, industrial, and pharmaceutical applications. In spite of the long history of using algae for medicinal purposes, there is no comprehensive information on medicinal algae in the literature. The aim of this review was to provide a systematic list of algae with medicinal properties. We reviewed more than 480 references. The studied algae were listed in a Table according to the systematic classification. General information on the algae phyla was presented and the medicinal taxa of each phylum were discussed. Results showed that about 500 algal taxa have medicinal potential, most of them are macroscopic and belong to the class Rhodophyta, followed by Phaeophyta and Chlorophyta. *Gracilaria* from Rhodophyta, *Sargassum* from Phaeophyta and *Caulerpa* from Chlorophyta are the genera having more taxa with medicinal properties. *Asparagopsis armata*, *Jania rubens*, *Porphyra haitanensis*, *Porphyra yezoensis* (Rhodophyta); *Ascophyllum nodosum*, *Ecklonia cava*, *Fucus vesiculosus*, *Laminaria japonica*, *Sargassum fusiforme* (Syn: *Hizikia fusiformis*), *Sargassum horneri*, *Sargassum pallidum*, *Sargassum siliquastrum*, *Undaria pinnatifida* (Phaeophyta); *Codium fragile* and *Ulva lactuca* (Chlorophyta) are the most cited taxa with various therapeutic effects. Their therapeutic effects are related to their polysaccharides, amino acids, fatty acids, pigments and some other compounds. However, it seems more clinical trials have to be done to confirm their applicability in some special disease.

Key words: Active component, Medicinal use, Phaeophyta, Rhodophyta

Introduction

In recent years, biologically active compounds from natural sources have gained significant popularity as an alternative to synthetic compounds due to their beneficial effects and reduced side effects. Therefore, numerous efforts are underway to produce biologically active substances from natural organisms for a variety of purposes.

The algae are a large and diverse group of photosynthetic organisms. These aquatic organisms have a variety of sizes and life cycles and grow much faster than terrestri-

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al plants. They contain many biologically active molecules, including pigments, polyphenols, polyunsaturated fatty acids, polysaccharides, etc., which are linked to various antioxidant, anti-inflammatory, anticancer, or anti-obesity effects beneficial to human health (Chénais, 2021).

Bioactive substances derived from algae

Algae produce different proportions of natural products and are a safe and renewable source for various bioactive compounds (Ismail et al., 2021). Algae are characterized by their pigments. Chlorophylls, carotenoids, and phycobiliproteins are major groups of algal pigments. Chlorophylls are green pigments and have a wide range of applications. Algal chlorophylls have various antimicrobial, anti-inflammatory, wound healing effects, and enhance blood cell formation (Chen et al., 2017). Carotenoids are yellow, orange, or red pigments that can be divided into two classes: carotenes and xanthophylls (Lee et al., 2008). β-carotene is the most common carotene have been reported to have antioxidant and antidiabetic activities (Miranda et al., 1998; Ruperez et al., 2009). Various xantophylls reported in different algal groups having various effects, for example fucoxanthin of brown algae and astaxanthin of some green algae possess antioxidant, anti-inflammatory, anti-cancer, anti-obesity and anti-diabetic effects (Guerin et al., 2003; Prabhu et al., 2009; Zhang et al., 2015). There are also some other xanthophylls including vaucheraxanthin, zeaxanthin, anteraxanthin, and violaxanthin (Abd El-Hack et al., 2019). Phycobiliproteins, which are blue or red pigments produced only by cyanobacteria, red algae and cryptomonads. The major phycobiliproteins are Phycoerythrin, phycocyanin, and allophycocyanin (Lee, 2008). The research indicated that phycobiliprotenis posses antioxidant, anti-inflammatory, antiviral, neuroprotective, anti-cancer activities (Bhat and Madyastha, 2000; Holdt and Kraan, 2011; Manirafasha et al., 2016). Furthermore, algal pigments are employed across various commercial applications.

Carbohydrates serve as the primary products of photosynthesis further can be stored as various polysaccharides consistent with algal taxa. These include sulfated polysaccharides such as galactans from red algae, ulvans from green algae, and fucans and alginate from brown algae, which have diverse biological applications (Ju et al., 2019). Laminaran, also known as laminarin is one of the major non-SPs found in brown algae. In total, among algal bioactive compounds, carbohydrates hold a distinctive position due to their extensive effects, which include antioxidant, antiviral, antitumor, anti-ulcerogenic, anticoagulant, prebiotic, anti-inflammation, and antibacterial activities (Ohta et al., 2009; Talero et al., 2015; Ju et al., 2019).

Microalgae have been considered as one of the most trustworthy sources of protein, with some species containing higher proportions of protein even than animal or plant sources (Ismail et al., 2021). One of the protein components of algae is mycosporine like amino acids, which show UV-absorbing effects and can be used in sunscreens and skin and hair care products (Hagino and Saito, 2010). Various properties have also been reported for algal proteins such as antibacterial, antioxidant, immunostimulating, anti-inflammatory antiviral, antidiabetic and analgesic activities (Dey et al., 2000; Ismail et al., 2021).

Microalgae are known for their large diversity of lipids and fatty acid composition (Ismail et al., 2021). Polyunsaturated fatty acids from algae especially omega-3 fatty acids have been reported to reduce the risk of cardiovascular disease and act as excellent antioxidans and anti-inflammatory improving heart function and acting against cancer and improving brain in children (Yurko-Mauro et al., 2010; Bharat et al., 2013; Chan et al., 2014; De los Reyes et al., 2014. Furthermore, PUFAs have antibiotic, antifungal and antimicrobial activities (Moreda-Piñeiro et al., 2012; Ramya and Muralitharan, 2019).

Minerals and vitamins are other components fonud in algae with different effects. The concentration of trace elements in marine algae sometimes is higher than terrestrial plants. (Ismail et al., 2021).

In addition to the primary metabolites, more than 8000 phenolic compounds are currently known from algae (Li et al., 2011). They vary from simple molecules such as phenolic acids to more complex pholrotannins. Alkaloids and flavonoids are other polyphenolic compounds with various properties (Gupta et al., 2011; Demay et al., 2019; Wekre et al., 2019).

Medicinal algae's systematic survey

Given the diversity of algae and their possible medical benefits, it seems necessary to provide a systematic review of the current state of the published articles. The present study is undertaken to provide a comprehensive list of medicinal algae. We conducted comprehensive online search of literature using PubMed, SpringerLink, ScienceDirect and Google Scholar databases. We used the phylla names as keywords in addition to "medicinal use" to identify the medicinal taxa related to algal phylla. Certain articles we obtained examined the taxa that were effective against a specific disease; for these review articles, we meticulously reviewed original articles carefully and included them in the reference list. On the other hand, other studies focused on the medicinal properties and active compounds of a specific taxon, these articles were directly referenced, and we also verified the citations included within them. Some taxa have been investigated merely from the view of chemical composition without any usage report, and were not included in this review. We reviewed more than 480 articles and extracted 496 Taxa with medicinal properties which groupd according to their phylum and were collected in Table 1. We cross-checked the taxa names with algaebase.org; in most cases, we kept the names given in the original articles due to their widespread recognition. However, in certain cases, we adopted the newly accepted taxonomical names.

In the literature we examined, the Rhodophycean algae were the most frequently referenced regarding biologically active compounds and medicinal properties, followed by Phaeophyta and Chlorophyta (Figure 1).

Rhodophyta

Rhodophyta is a group of red-colored algae that have sulfated polysaccharides in the cell wall, unstacked thylakoids, phycobilin pigments, floridean starch, and chloroplasts devoid of endoplasmic reticulum, but lack flagella. Phycoerythrin is caused the red color of these algae. They also have phycocyanin, allophycocyanin, chlorophyll a, beta-carotene, and xanthophylls. They are capable to absorb blue and green wavelengths due to the Phycobilin proteins that they contained, which they are found in deeper waters where these algae inhabit. The majority of the red algae are commonly called red seaweeds and hence, marine so, only 3% of all the Rhodophyte species are freshwater and the diversity of species in these algae increases from the poles to the equator. Additionally, the red algae species mostly inhibit in freshwater are found in rivers and streams, while a few are found in ponds, lakes, hot springs, caves, and wet soils (Wehr and Sheat, 2003; Lee, 2008). The red algae reserve food as the floridean starch, stored in the cytoplasm. The most famous products obtained from red algae are agar and carrageenan. Agar is used in microbiological and molecular biological studies. Some Rhodophytes are also eaten throughout Southeast Asia. They have diverse medicinal effects including antimicrobial, antiviral, antioxidant, anti-inflammatory, analgesic and antipyretic, anticoagulant and antithrombotic, antidiabetic, anti-obesity, antihypertensive, anticancer and antiproliferative activities, acetylcholinesterase inhibitory in alzheimer disease and skin care (Table 1).

The genus that is the most diverse from a medicinal perspective t is *Gracilaria*, which comprises 19 species. It is followed by *Gelidium*, *Laurencia* and *Porphyra*. The most frequently cited taxa include *Asparagopsis armata*, *Jania rubens*, *Porphyra haitanensis*, *Porphyra yezoensis*. *Gracilaria* which has a total of 200 accepted species (Guiry and Guiry, 2022), is a genus of red algae with considerable economic importance as an agarophyte (Oliveira et al., 2000). This red alga is distributed globally, however, it prefers warm waters and isn't found in the Arctic. *Gelidium* is also an agarophyte known for producing high-quality agar, while *Porphyra* is recognized for its nutritional value. One of the main compounds extracted from most of the rhodophytes with medicinal properties, is mycosporine-like

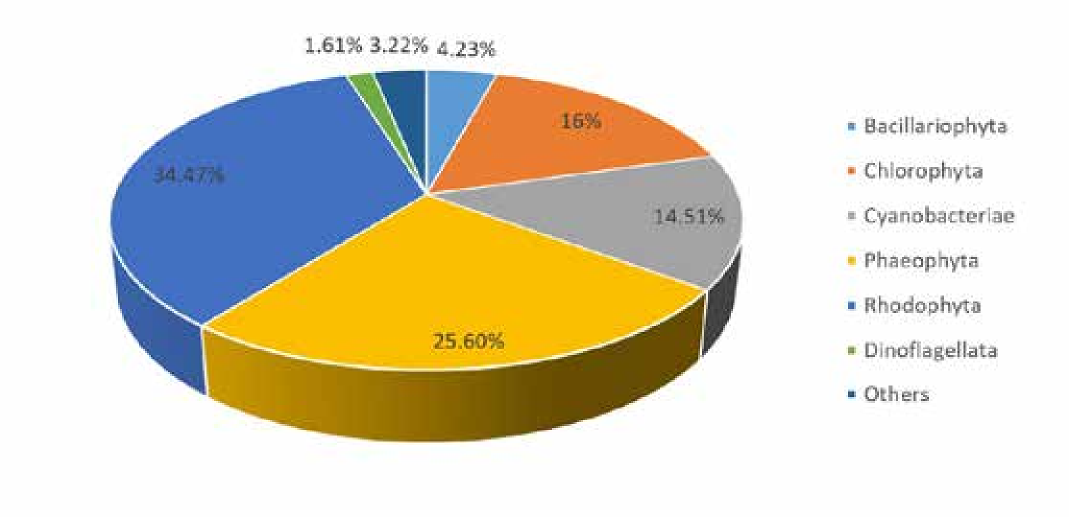

Fig. 1. The relative abundance of medicinal taxa associated to each phylum

amino acids (MAAs) giving them UV-protective effects which makes them useful in skin care products (Table 1). Carrageenans, agars and porphyrans extracted from red algae are types of sulfated polysaccharides which are responsible for their antioxidant and immunostimulatory effects (Manlusoc et al., 2019). Phycobiliprotein pigments of red algae along with above mentioned products have anticancer and antitumor effects (Zhou et al., 2005, 2006; Gantar et al., 2012; Jiang et al., 2017; Luo et al., 2015). Due to their sulphate content, carrageenans have anticoagulant activity (Necas and Bartosikova, 2013; Güven et al., 2019). Depolymerized agar also increases anticoagulant ability (Ismail et al., 2020). According to the data presented in Table 1, proteins, including MAAs rank first among the reported active compounds from rhodophyte taxa, while carbohydrate; specially sulfated polysaccharides, follow the next position (Figure 2). For this phylum, other compounds include terpenes, vitamins, and trace elements (Figure 2).

Phaeophyta

Brown algae are categorized as a class within the phylum Heterokontophyta (e.g. Lee, 2008), or ranked as a separate phylum (Phaeophyta, e.g. Papenfuss, 1951). However, it has considered recently as a class within the phylum Ochrophyta (Guiry and Guiry, 2022). The class Phaeophyceae consists of macroscopic algae that are exclusively marine, ranging from fillamentous forms to giant kelps (Barsanti and Gualtieri, 2006). Their brown color arises from the dominance of the carotenoid pigment, fucoxanthin, along with phaeophycean tannins in certain cases, in addition to the chlorophylls a, c1 , and c2 (Lee, 2008).

Phaeophyta are extremely valuable and known for commercial products, alginic acid and its derivatives, which, due to their viscous properties, are considerably used in industry. Fucoidans are other polysaccharides present in phaeophyta with various biological activities such as antiviral, anticoagulant, antitumoral, and antioxidant ac-

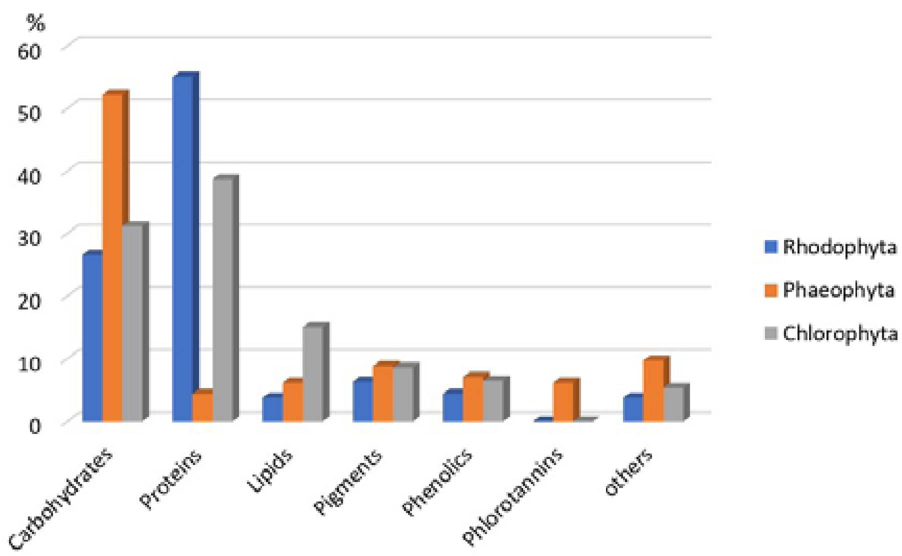

Fig. 2. Relative rate of major substances in active componds reported for three main phylla according to the data from Table 1-3

tivities (Cosenza et al., 2017; Senthilkumar et al., 2017; Wang et al., 2019; Ponce and Stortz, 2020). Unlike rhodophyta, polysaccharides are the primary active compounds reported from phaeophytes, whereas proteins have been reported infrequently (Figure 2). Furthermore, more than 1140 secondary metabolites have been extracted from Phaeophyta, most of which include diterpenes, phlorotanins, and small C_{11} acetogenins having various ecological roles (Amsler, 2008). Phlorotannins are abundant in brown algae in comparison to other seaweeds. Strong effects of phlorotannins have been reported against oxidative stress, cancer, inflammation, allergy, diabetes, and other disorders (Kim and Himaya, 2011). As with rhodophyta, terpenoides, vitamins, and trace elements were considered under the general group of others (Figure 2).

Approximately, 2040 species across 265 genera have been reported, from which 95% are marine. Notably, taxa belong to the orders Laminariales, Fucales, and Dictyotales have been noticed for their chemical composition (Mekinić et al., 2019). These orders are also among the most species-rich too. Most taxa, including those from the genera *Laminaria, Macrocystis, Sargassum* and *Fucus*, hold significant commercial value (Guiry and Guiry, 2022). Among the medicinal phaeophyceans, *Sargassum* stands out as the genus with the highest species diversity. *Sargassum*, which belongs to the order Fucales, has a worldwide distribution, containing 359 different species (Guiry and Guiry, 2022). In the literature we reviewed, 37 taxa of this genus have been identified as possessing medicinal properties, which range from anti-inflammatory and antioxidant effects to antitumor, anti- HIV, and Alzheimer disease activity. Among the phaeophyceans known for their medicinal benefits are *Ascophyllum nodosum*, *Ecklonia cava*, *Fucus vesiculosus*, *Laminaria japonica*, *Sargassum fusiforme* (Syn: *Hizikia fusiformis*), *Sargassum horneri*, *Sargassum pallidum*, *Sargassum siliquastrum*, *Undaria pinnatifida* (Table 2).

Chlorophyta

Chlorophyta are commonly known as green algae and are the most diverse group of algae, with about 8,000 species (Guiry and Guiry, 2022). There are many different species with the diverse morphology of the thallus, some are unicellular and some are multicellular. However, some are colonial, some are free-living, and others are coenocytic. Chlorophyta possess chlorophylls a and b, although the major pigment is chlorophyll b. Although cholorophyta live in both freshwater and marine habitats, but 90% of those are freshwater species. Those that live in marine habitats largely inhabit tropical environments. There are a small number of terrestrial species; these largely dwell on rocks or trees (Wehr and Sheat, 2003; Lee, 2008).

Caulerpa is one of the marine chlorophyceans with nutritional values and also with medicinal usages including antibacterial, antitumoral, antiviral, hypoxia-inducing factor, antinociceptive and anti-inflammatory mostly related to its alkaloids especially caulerpin (Mehra et al., 2019). However, there are some well-known chlorophyceans with extensive industrial and commercial uses including *Chlorella vulgaris*, *Dunaliella* sp. and *Scenedesmus*

Table 1. Medicinal taxa from phylum Rhodophyta. MAAs: mycosporin like amino acids.

Taxa	Medicinal effect	Active component	Reference
Acanthophora spicifera (M.Vahl) Børgesen	Sulfated Polysaccharides; MAAs	antioxidant; anticancer; UV protect	Anand et al., 2018
Acanthophora muscoides (Linnaeus) Bory	Sulfated polysaccharides	Anti-inflammatory activity	Quindere et al., 2013
Acanthophora spicifera (M.Vahl) Børgesen		Antibacterial; antifungal	Pandian et al., 2011
Actinotrichia fragilis (Forsskål) Børgesen	MAAs	UV protecting	Karsten et al., 1998b
Agardhiella ramosissima (Harvey) Kylin	Sulfated polysaccharides	Anti-inflammatory activity	Batista et al., 2014
Ahnfeltiopsis flabelliformis (Harvey) Masuda	Sulfated polysaccharides	Anti-inflammatory, anticoagulant	Kravchen et al., 2016
Amphiroa rigida J.V.Lamouroux	MAAs	UV protecting	Gröniger et al., 2000
Amphiroa sp.	MAAs	UV protecting	Gröniger et al., 2000
Asparagopsis armata Harvey	Sulfated polysaccharides; MAAs	UV protecting; antileishmania	Genovese et al., 2009
Asparagopsis taxiformis (Delile) Trevisan	MAAS	UV protecting effect; antileishmania	Gröniger et al., 2000
Boergeseniella fruticulosa (Wulfen) Kylin		Antileishmania	Allmendin et al., 2010
Bostrychia calliptera (Montagne) Montagne	MAAs	UV protecting effect	Karsten et al., 1998b
Bostrychia montagnei Harvey	MAAs	UV protecting	Karsten et al., 1998b
Bostrychia moritziana (Sonder ex Kützing) J.Agardh	MAAs	UV protecting	Karsten et al., 1998b
Bostrychia pinnata Harvey ex J.Agardh	MAAs	UV protecting	Karsten et al., 1998b
Bostrychia radicans (Montagne) Montagne	MAAs	UV protecting	Karsten et al., 1998b
Bostrychia simpliciuscula Harvey ex J.Agardh	MAAs	UV protecting	Karsten et al., 1998b
Bostrychia tenella (J.V.Lamouroux) J.Agardh	MAAs	UV protecting; antileishmania	Sabina et al., 2011
Botryocladia leptopoda (J.Agardh) Kylin		Antileishmania	Sabina et al., 2011
Bryothamnion triquetrum (S.G. Gmelin) M. Howe		Antileishmania, hepatoprotective	García et al., 2012
Calliblepharis jubata (Gooden. & Woodward) Kützing		Antiprotozoa	Allmendin et al., 2010
Callophyllis japonica Okamura		Antioxidant	Kang et al., 2005
Caloglossa apomeiotica J.A.West & Zuccarello	MAAs	UV protecting	Karsten et al., 1998b
Caloglossa leprieurii (Montagne) G.Martens	MAAs	UV protecting	Karsten et al., 1998b
Caloglossa ogasawaraensis Okamura	MAAs	UV protecting	Karsten et al., 1998b
Caloglossa stipitata E.Post	MAAs	UV protecting	Karsten et al., 1998b
Centroceras clavulatum (C.Agardh) Montagne		Antileishmania	Sabina et al., 2011
Ceramium nodulosum (Lightfoot) Ducluzeau	MAAs	UV protective effect	Karsten et al., 1998a
Ceramium rubrum C.Agardh	MAAs	UV protective, antileishmania	Freile et al., 2008
Ceramium virgatum Roth		antileishmania	Allmending et al., 2010
Ceratodictyon spongiosum Zanardini	Phenolic componds and peptides	Analgesic activity	Tan et al., 2000
Chondria armata (Kützing) Okamura	MAAs	UV protective effect	Karsten et al., 1998b
Chondrococcus hornemanni (Mert.) Schmitz		antileishmania	Lakshmi, et al., 2014
Chondrus crispus Stackhouse	Sulfated Polysaccharides; MAAs; phycoerythrin,	UV protect, antiprotozoal, antidiabetic	Ismail et al., 2020
Chondrus ocellatus Holmes	Carrageenan	Antitumor activity	Zhou et al., 2006
Chylocladia verticillata (Lightf.) Bliding		antileishmania	Allmendin et al., 2010
Claviclonium ovatum (J.V.Lamouroux) Kraft Min-Thein		antileishmania	Allmendin et al., 2010
Corallina elongata J.Ellis & Solander	MAAS	UV protective effect	Sinha et al., 1998
Corallina granifera Ell. et Sol.		antiprotozoa	Süzgeç et al., 2011
Corallina mediterranea J.E.Areschoug		Antifungal activity	Saleh et al., 2018
Corallina officinalis Linnaeus	MAAs; Sulfated polysaccharides	UV protective; antiprotozoa	Allmendin et al., 2010

Taxa	Medicinal effect	Active component	Reference
Cryptopleura ramosa (Hudson) L.Newton		antiprotozoa	Allmendin et al., 2010
Curdiea racovitzae Hariot	MAAs	UV protective effect	Hoyer et al., 2001
Cystoclonium purpureum (Hudson) Batters	MAAs	UV protective effect; antiprotozoa	Gröniger et al., 2000
Dasya pedicellata (C. Agardh) C.Agardh		antiprotozoa	Süzgeç, et al., 2011
Devaleraea ramentacea (Linnaeus) Guiry	MAAs	UV protective effect	Karsten et al., 1998a
Dichotomaria obtusata (J.Ellis & Solander) Lamarck	Polysaccharides and phenols	Anti-inflammatory and analgesic	Vázquez et al., 2011
Dilsea carnosa (Schmidel) Kuntze		Antiprotozoal	Vonthron, et al., 2011
Dumontia incrassata (O.F.Müller) J.V.Lamouroux	MAAs	UV protective effect; antiprotozoa	Allmendin, et al., 2010
Eucheuma cottonii Weber Bosse	Carrageenan	Antioxidant, photoprotective	Thevanayag et al., 2014
Eucheuma spinosum J.Agardh	Carrageenan	Antioxidant, photoprotective	Thevanayag et al., 2014
Furcellaria lumbricalis (Hudson) J.V.Lamouroux		Skin anti-aging; antiprotozoa	Al-Bader et al., 2012
Galaxaura oblongata (J.Ellis & Solander) J.V.Lamouroux	MAAs	UV protective	Karsten et al., 1998b
Ganonema farinosum (J.V.L.) K.-C.Fan & Y.-C.Wang	MAAs	UV protective	Karsten et al., 1998b
Galaxaura rugosa (J.Ellis & Solander) J.V.Lamouroux	Essential amino acids		Pirian et al., 2020
Gelidiella acerosa (Forsskål) Feldmann & Hamel	MAAs	Antioxidant; UV protective	Murugan et al., 2013
Gelidium amansii (J.V.Lamouroux) J.V.Lamouroux	MAAs	UV protecting; antidiabetic	Seo et al., 2012
Gelidium crinale (Hare ex Turner) Gaillon		Antiprotozoal	Süzgeç et al., 2011
Gelidium foliaceum (Okamura) E.M.Tronchin		Antioxidant activity	Rengasamy et al., 2015
Gelidium latifolium (Greville) Bornet	MAAs	UV protecting	Nakamura et al., 1982
Gelidium pristoides (Turner) Kützing	Sulfated polysaccharides	Antioxidant, Antiamyloidogenic	Olasehinde et al., 2019
Gelidium pulchellum (Turner) Kützing		Antiprotozoa	Allmendin, et al., 2010
Gelidium pusillum (Stackhouse) Le Jolis	MAAs; phycoerythrin	UV protective; antidiabetic	Mittal et al., 2018
Gelidium sesquipedale (Clemente) Thuret	MAAs	UV protective effect	Karsten et al., 1998a
Gelidium sp.	MAAs	UV protective effect	Sinha et al., 1998
Georgiella confluens (Reinsch) Kylin	MAAs	UV protecting effect	Hoyer et al., 2000
Gigartina skottsbergii Setchell & N.L.Gardner	MAAs	UV protecting effect	Hoyer et al., 2000
Gloiopeltis furcata (Postels & Ruprecht) J.Agardh	Sulfated polysaccharides	antioxidant activity	Shao et al., 2013
Gloiopeltis tenax (Turner) Decaisne	fatty acids, sesquiterpenes, ketones, sterols	Antibacterial and antioxidant	Zheng et al., 2012
Gracilaria birdiae E.M.Plastino & E.C.Oliveira	Sulfated Polysaccharides: agar	Anticoagulant activity	Ismail et al., 2020
Gracilaria bursa-pastoris (S.G.Gmelin) P.C.Silva	Agar	anticoagulants; antiprotozoa	Armeli et al., 2016
Gracilaria caudata J.Agardh	Sulfated polysaccharides	antioxidant activity	Alencar et al., 2019
Gracilaria cervicornis (Turner) J.Agardh	Sulfated polysaccharides	Antidiarrheal	Bezerra et al., 2018
Gracilaria changii (B.M.X. & I.A.A) I.A.A., Zhang &Xia	MAAs	UV protective effect; antidiabetic	Chan et al., 2015
Gracilaria cornea J.Agardh	MAAs, sulfated polysaccharides	UV protective; anti-inflammatory	Coura et al., 2017
Gracilaria corticata (J.Agardh) J.Agardh	Sulfated Polysaccharides	Antioxidant; anticancer; antiprotozoa	Fouladvand, et al., 2011
Gracilaria debilis (Forsskål) Børgesen	Sulfated Polysaccharides	Anticoagulant, antioxidant activity	Sudharsan et al., 2015
Gracilaria domingensis (Kützing) Sonder ex Dickie	MAAs	photoprotective effects; sunscreen	Cardozo et al., 2011
Gracilaria eucheumatoides Harvey	MAAs	UV protecting	Karsten et al., 1998b
Gracilaria foliifera (Forsskål) Børgesen		anticancer	Erfani et al., 2015
Gracilaria gracilis (Stackhouse) Steentoft,Irvine & Farnham	Agar	Laxative,anticoagulants; antiprotozoa	Allmending et al., 2010
Gracilaria lemaneiformis (Bory) Greville	Phenolic compounds	Antidiabetic	Ismail et al., 2020
Gracilaria opuntia Durairatnam	Sulfated galactans	Antidiabetic	Makkar& Chakr, 2017
Gracilaria rubra J.Agardh	Sulfated polysaccharides	Antioxidant, immunomodulatory	Di et al., 2017
Gracilaria salicornia (C.Agardh) E.Y.Dawson	MAAs	Antiprotozoa,antibacterial;UV protect	Fouladva, et al., 2011

Taxa	Medicinal effect	Active component	Reference
Gracilaria tenuistipitata C.F.Chang & B.-M.Xia	MAAs	Anti cancer; photoprotective	Cardozo et al., 2011;
Gracilaria viridis A.Sfriso, M.Wolf, Sciuto & I.Moro		antiprotozoa	Armeli et al., 2016
Gracilariopsis lemaneiformis (Bory) Dawson & Foldvik	Sulfated polysaccharides	Antioxidant, immunomodulatory	Wang et al., 2019
Grateloupia elliptica Holmes		antiobesity	Lee et al., 2020
Grateloupia indica Børgesen	Sulfated polysaccharides	anticoagulant	Holtkamp et al., 2009
Grateloupia livida (Harvey) Yamada	Sulfated Polysaccharides	Anticoagulant, antioxidant activity	Tang et al., 2017
Grateloupia turuturu Y.Yamada		edible	Denis et al., 2010
Gymnogongrus antarcticus Skottsberg	MAAs	UV protecting effect	Hoyer et al., 2000
Gymnogongrus griffithsiae (Turner) C.Martius	MAAs	UV protective effect	Karsten et al., 1998a
Gymnogongrus turquetii Hariot	MAAs	UV protective effect	Hoyer et al., 2000
Halopithys incurvus (Hudson) Batters		Antiprotozoa	Allmending et al., 2010
Heterosiphonia japonica Yendo	Phycoerythrin	antidiabetic	Ismail et al., 2020
Halurus equisetifolius (Lightfoot) Kützing		Antiprotozoa	Allmending et al., 2010
Hypnea flagelliformis Greville ex J.Agardh	Fatty acids	Antibacterial activity	Jassbi et al., 2013
Hypnea musciformis (Wulfen) J.V.Lamouroux	Sulfated polysaccharides	Anti-inflammatory, antidiarrheal, gastroprotective; antifungal	Sousa et al., 2016; Saleh et al., 2018
Hypnea spinella (C.Agardh) Kützing	MAAs	UV protective effect	Karsten et al., 1998b
Iridaea chordata (Turner) Bory	MAAs	UV protective effect	Hoyer et al., 2000
Jania rubens (Linnaeus) J.V.Lamouroux	Sulfated Polysaccharides; MAAs; fatty acids	UV protect; antimicrobial, anticancer	Gheda et al., 2018
Kallymenia antarctica Hariot	MAAs	UV protecting	Hoyer et al., 2000
Kappaphycus alvarezii (Doty) L.M.Liao	Sulfated polysaccharide: Carrageenan; phenolics	Antioxidant, anticancer, antibacterial	Suganya et al., 2016
Laurencia aldingensis Y.Saito & Womersley		Antiprotozoa	Da Silva et al., 2014
Laurencia cartilaginea Yamada	MAAs	UV protecting	Karsten et al., 1998b
Laurencia dendroidea J.Agardh		Antiprotozoa; antidiabetic, antioxidant	Nguyen et al., 2019
Laurencia microcladia Kützing		antiprotozoa	Da Silva et al., 2014
Laurencia obtusa (Hudson) J.V.Lamouroux	Sulfated Polysaccharides; MAAS	Antioxidant, anticancer, gastroprotective; UV protect; hepatit C	Lajili et al., 2018; Gheda et al., 2016
Laurencia papillosa (C.Agardh) Greville	Sulfated Polysaccharides	anticancer activity; antifunga	Saleh et al., 2018
Laurencia undulata Yamada	Floridoside	anti-neuroinflammatory	Kim et al., 2013
Lithophyllum expansum Philippi	MAAs	UV protective effect	Karentz et al., 1998a
Lithophyllum incrustans Philippi	MAAs	UV protective effect	Karentz et al., 1998a
Lithothamnion cf. *antarcticum* (Hook & Harv) Heydrich	MAAs	UV protective effect	Karentz et al., 1991
Lithothamnion muelleri Lenormand ex Rosanoff	Sulfated Polysaccharides	antiviral activity	Malagoli et al., 2014
Lomentaria articulata (Hudson) Lyngbye		Antiprotozoa	Almendig et al., 2010
Mastocarpus stellatus (Stackhouse) Guiry	Sulfated Polysaccharides; MAAs; R-phycoerythrin	Antioxidant; UV protect; antiprotozoa	Nguyen et al., 2017
Melanothamnus afaqhusainii M.Shameel		Antiprotozoa	Sabina et al., 2011
Myriogramme mangini (Gain) Skottsberg	MAAs	UV protecting effect	Hoyer et al., 2000
Nemalion helminthoides (Velley) Batters	Sulfated Polysaccharides	Immunomodulatory activity	Pérez et al., 2014
Neuroglossum ligulatum (Reinsch) Skottsberg	MAAs	UV protecting effect	Hoyer et al., 2000
Notophycus fimbriatus R.L.Moe	MAAs	UV protecting effect	Hoyer et al., 2000
Ochtodes secundiramea (Montagne) M.Howe	monoterpenes	antiprotozoa	Machado et a., 2015
Osmundaria obtusiloba (C.Agardh) R.E.Norris		Antiprotozoal	Lira et al., 2015
Osmundea hybrid (De Candolle) K.W.Nam		Antiprotozoa	Allmending et al., 2010
Osmundea pinnatifida (Hudson) Stackhouse		Antiprotozoa; antidiabetic	Ismail et al., 2020

Taxa	Medicinal effect	Active component	Reference
Pachymenia orbicularis (Zanar) Setchell & N.L.Gardner	MAAs	UV protecting effect	Hoyer et al., 2000
Palisada flagellifera (J.Agardh) K.W.Nam		Antiprotozoal	Da Silva et al., 2014
Palisada perforata (Bory) K.W.Nam		Antiprotozoal; antioxidant and antidiabetic	Pirian et al., 2017
Palmaria decipiens (Reinsch) R.W.Ricker	MAAs	UV protective effect	Hoyer et al., 2000
Palmaria palmata (Linnaeus) F.Weber & D.Mohr	Polysaccharids, fatty acids; MAAs;	UV protect; antioxidant , antidiabetic	Ismail et al., 2020
Phyllophora antarctica A.Gepp & E.S.Gepp	MAAs	UV protective effect	McClin& Karentz, 1997
Phyllophora appendiculata Skottsberg	MAAs	UV protective effect	Karentz et al., 1991
Plocamium cartilagineum (Linnaeus) P.S.Dixon	MAAs	UV protecting effect; antiprotozoa	Allmendin, et al., 2010
Plocamium telfairiae		Antiobesity; anticancer	Lu et al., 2020
Polyides rotundus (Hudson) Gaillon		antiprotozoa	Allmendin, et al., 2010
Polysiphonia arctica J.Agardh	MAAs	UV protective effect	Karsten et al., 1998a
Polysiphonia urceolata (Lightfoot ex Dillwyn) Greville	MAAs; R- phycoerythrin	UV protective effect; antioxidant	Gröniger et a., 2000; Fitzgerald et al., 2013
Porphyra endivifolium (Gepp &Gepp) Chamberlain	MAAs	UV protecting effect	Hoyer et al., 2000
Porphyra haitanensis T.J.Chang & B.F.Zheng	Sulfated Polysacchrides, porphyrin,	Antioxidant, immunomodulatory	Zhang et al., 2018
Porphyra linearis Greville		Antiprotozoal	Allmendin, et al., 2010
Porphyra purpurea (Roth) C.Agardh	MAAs	UV protective effect	Karsten et al., 1998a
Porphyra rosengurttii Coll & J.Cox	MAAs	UV protective effect in skin	De la Coba et al., 2009
Porphyra sp.	Phycoerythrobilin; porphyrin	Antioxidant activity	Kuda et al., 2005
Porphyra umbilicalis Kützing	Vitamins; MAAs	UV protective effect	Mercurio et al., 2015
Porphyra yezoensis Ueda	MAAs; sulfated polysaccharides, porphyran	UV protecting; anti-inflammatory	Ismail et al., 2020
Porphyridium sp.	Carrageenan	Anti-melanogenesis	Takema and Seiji, 1984
Porphyridium purpureum (Bory) K.M.Drew & R.Ross	Fatty acid: EPA, DHA	anti-inflammatory, heart disease	Ohta et al., 1993
Portieria hornemannii (Lyngbye) P.C.Silva	Pentahalogenated monoterpene	antitumor	Fuller et al., 1992
Pseudolithophyllum expansum (Philippi) Me.Lemoine	MAAs	UV protcive effect	Sinha et al., 1998
Pterocladia capillacea (S.G.Gmelin) Bornet	Sulfated Polysaccharides	Anticoagulant; anti hepatitis C	Gheda et al., 2016
Ptilota plumosa C.Agardh	MAAs	UV protective effect	Karsten et al., 1998a
Rhodomela confervoides (Hudson) P.C.Silva	Phenolic compounds	Anticancer activity	Liu et al., 2011
Rhodomela virgata Kjellman	MAAs	UV protective effect	Karsten et al., 1998a
Rhodymenia subantarctica R.W.Ricker	MAAs	UV protecting	Hoyer et al., 2000
Rissoella verruculosa (A.Bertoloni) J.Agardh	MAAs	UV protective effect	Gröniger et al., 2000
Sarcothalia papillosa (Bory) Leister	MAAs	UV protective	Hoyer et al., 2000
Schizymenia dubyi (Chauvin ex Duby) J.Agardh		Anti-melanogenesis	Cha et al., 2011
Scinaia boergesenii C.K.Tseng	MAAs	UV protective	Karsten et al., 1998b
Scinaia furcellata (Turn.) J. Agardh		antiprotozoa	Orhan et al., 2006
Scinaia hatei Børgesen		Antiprotozoa	Sabina et al., 2005
Scinaia indica Børgesen		antiprotozoa	Sabina et al., 2005
Solieria chordalis (C.Agardh) J.Agardh	carageenan	Antiviral activity	Boulho et al., 2017
Solieria filiformis (Kützing) P.W.Gabrielson	Sulfated Polysaccharides; Polyphenols	Anticoagulant, antioxidant	Morán et al., 2018
Sphaerococcus coronopifolius Stackhouse	diterpens	Antibaceterial; antitumor; antiviral	Rodrigues et al., 2015
Spyridia filamentosa (Wulfen) Harvey	MAAs	UV protective	Karsten et al., 1998b
Stictosiphonia hookeri (Harvey) Harvey	MAAs	UV protective	Karsten et al., 1998b
Stictosiphonia tangatensis (Post) R.J.King & Puttock	MAAs	UV protective	Karsten et al., 1998b
Vidalia obtusiloba (Mertens ex C.Agardh) J.Agardh	Phenolic compounds and peptides	Analgesic activity	Tan et al., 2000

Table 2. Medicinal taxa from phylum phaeophyta.

Taxa	Medicinal effect	Active component	Reference
Adenocystis utricularis (Bory) Skottsberg	Fucoidans	Antiviral activity	Poncde et al., 2003
Ascophyllum nodosum (Linnaeus) Le Jolis	MAAs; sulfated polysaccharies: fucoidan	Antidiabetic,UV protect; Antileishmanial	Okimura et al., 2019
Bifurcaria bifurcata R. Ross		Antileishmanial activity	Spavieri et al., 2010
Canistrocarpus cervicornis (Kützing) Paula&Clerck		Antileishmanial activity	Dos Santos et al., 2011
Chnoospora minima (Hering) Papenfuss	Sulfated polysaccharides	Anti-inflammatory activity	Fernando et al., 2017
Chorda filum (Linnaeus) Stackhouse		Antileishmanial activity	Spavieri et al., 2010
Chorda tomentosa Lyngbye	MAAs	UV protective	Karsten et al., 1998a
Colpomenia peregrina Sauvageau		Antileishmanial activity	Spavieri et al., 2010
Colpomenia sinuosa (Mertens ex Roth) Derbès & Solier	Phenolic contents	Antioxidant; antibacterial	Moein et al., 2015
Costaria costata (C.Agardh) De A.Saunders	Fucoidan	Skin anti-aging	Moon et al., 2009
Cystoseira baccata (S.G. Gmel) P.C.		Antileishmanial activity	Spavieri et al., 2010
Cystoseira barbata (Stackhouse) C. Agardh	Sulfated polysaccharides	Antimycobacterial, antioxidant	Süzgeç et al., 2011
Cystoseira compressa (Esper) Gerloff & Nizamuddin	Sulfated polysaccharides	antioxidant activity; antidiabetic	Gheda et al., 2021
Cystoseira crinata (Desf.) Duby	Sulfated polysaccharides	Antileishmanial; Antihyperlipidem	Süzgeç et al., 2011
Cystoseira indica (Thivy & Doshi) Mairh	Sulfated Polysaccharides	Antioxidant, anticancer	Taheri et al., 2017
Cystoseira myrica (S.G.Gmelin) C.Agardh	phenolics	Anticancer; antibacterial; antioxidant	Moein et al., 2015;
Cystoseira tamariscifolia (Hudson) Papenf.		Antileishmanial activity	Spavieri et al., 2010
Desmarestia aculeata (Linnaeus) J.V.Lamouroux	MAAs	UV protective effect	Sinha et al., 1998
Desmarestia menziesii J.Agardh	MAAs	UV protecting	Karsten et al., 1998a
Dictyopteris delicatula J.V.Lamouroux	Sulfated Polysaccharides	antioxidant activity	Costa et al., 2010
Dictyopteris divaricata (Okamura) Okamura	Sulfated Polysaccharides	Antioxidant, immunomodulatory	Cui et al., 2018
Dictyopteris polypodioides (A.P. de Can.) J.V.Lamouroux		Antileishmanial activity	Vonthron et al., 2011
Dictyosiphon foeniculaceus (Hudson) Greville	MAAs	UV protecting	Karsten et al., 1998a
Dictyota bartayresii J.V.Lamouroux	MAAs	UV protective	Karsten et al 1998b
Dictyota caribaea Hörnig and Schnetter		Antileishmanial activity	Freile et al., 2008
Dictyota cervicornis Kützing	Sulfated Polysaccharides	Antioxidant activity; antibacterial	Ghaffari et al., 2017
Dictyota ciliolata Sonder ex Kützing		Antileishmanial activity	Lira et al., 2015
Dictyota dichotoma (Hudson) J.V.Lamouroux		Antiprotozoa	Spavieri et al., 2010
Dictyota menstrualis (Hoyt) Schnette & Weber-Peukert	diterpene	Antileishmanial, antiviral activity	Lira et al., 2015
Dictyota mertensii (Martius) Kützing		Antileishmanial activity	Dos Santo et al., 2014
Dictyota pfaffii	Diterpene	Antiviral activity	Abrantes et al., 2010
Durvillaea Antarctica (Chamisso) Hariot	Amino acids; saturated fatty acids; tocopherol	Edible	Ortiz et al., 2006
Ecklonia cava Kjellman	Eckol, dieckol and 8,8'-bieckol; Polysaccharides; Phlorotannins	Antioxidant, anti-apoptotic; anti-inflammator; anticancer; anti aging	Lee et al., 2019; Kim et al., 2023
Ecklonia kurome Okamura	Phlorotannin	Antibacterial, antioxidant	Shibata et al., 2008
Ecklonia maxima (Osbeck) Papenfuss	Fucoidan	Antidiabetic activity	Daub et al., 2020
Ecklonia radiata (C.Agardh) J.Agardh	Polysaccharides	Preventing apoptosis; Alzeimer	Alghazwi et al., 2020
Ecklonia stolonifera Okamura	Phloroglucinol derivatives; Phlorotannins	Tyrosinase inhibitory,anti aging	Kang et al., 2004
Eisenia bicyclis (Kjellman) Setchell	Fucoxanthin; phlorotannins	Antidiabetic; antioxidant	Jung et a., 2012
Endarachne binghamiae J.Agardh		Anti-melanogenesis	Cha et al., 2011
Fucus ceranoides Linnaeus		Antileishmanial activity	Spavieri et al., 2010

Taxa	Medicinal effect	Active component	Reference
Fucus evanescens C.Agardh	Sulfated Polysaccharides	anticancer activity	Vishchuk et al., 2013
Fucus serratus Linnaeus		Antileishmanial activity	Spavieri et al., 2010
Fucus spiralis Linnaeus	MAAS	UV protective effect	Sinha et al., 1998
Fucus vesiculosus Bory	Sulfated Polysaccharides	antioxidant; Skin anti aging	Liewert et al., 2017
Halidrys siliquosa (Linnaeus) Lyngb.		Antileishmanial activity	Spavieri et al., 2010
Halopteris scoparia (Linnaeus) Sauvageau	MAAs	UV protecting	Gröniger et al., 2000
Himanthalia elongata (Linnaeus) S.F. Gray		Antileishmanial activity	Spavieri et al., 2010
Hydroclathrus clathratus (C.Agardh) M.Howe	MAAs	UV protecting	Karsten et al., 1998b
Ishige okamurae Yendo	Diphlorethohydroxycarmalol	Antioxidant; antiaging; whitening	Heo et al., 2010
Kjellmaniella crassifolia Miyabe	Sulfated Polysaccharides	Immunomodulatory;	Peng et al., 2018
Laminaria cichorioides Miyabe	Sulfated Polysaccharides: Fucoidan	dermatitis; anti-skin cancer	Yang, 2012
Laminaria digitata (Hudson) J.V.Lamouroux		Antileishmanial activity	Spavieri et al., 2010
Laminaria japonica Areschoug	Sulfated Polysaccharides: fucoidan	Antioxidant, antibacterial anticoagulant, antiangiogenic, antidiabetic; anticancer	Li et al., 2014; Wei et al., 2019
Leathesia difformis (Linnaeus) Aresch.		Antileishmanial activity	Spavieri et al., 2010
Lessonia trabeculata Villouta & Santelices	Posysaccharides: alginic acid		Chandia et al., 2001
Lessonia vadosa Searles	Sulfated polysaccharides: fucoidan	Anticoagulant and elicitor	Chand and Mats, 2008
Lobophora variegata (Lamouroux) Womersley ex Olive.		Antileishmanial activity	Freile et al., 2008
Myagropsis myagroides (Mertens ex Turner) Fensholt		anti-neuroinflammatory activities	Kim et al., 2013
Nannochloropsis oceanica Suda & Miyashita		anti-neuroinflammatory	Choi et al., 2017
Nemacystus decipiens (Suringar) Kuckuck	sulfated polysaccharides	Antithrombotic	Chaves et al., 2018
Padina australis Hauck	Fatty acids; sulfated polysaccharide	Anticancer, anti-inflammatory	Aisya et al., 2014
Padina boergesenii Allender & Kraft		Antioxidant and antibacterial	Ramezanp et al., 2021
Padina crassa Yamada	MAAs	UV protective effect	Karsten et al., 1998
Padina gymnospora (Kützing) Sonder	sulfated polysaccharides	Antioxidant and antibacterial	Moheimani et al., 2021
Padina pavonica (Linnaeus) Thivy		Antibacterial	Sheikhakbari, 2016
Padina tenuis Bory		Anti-melanogenesis	Quah et al., 2014
Padina tetrastromatica Hauck	Sulfated polysaccharides	Anticancer, antidiabetic; antiaging	Jose et al., 2018
Padina antillarum (Kützing) Piccone		Antibacterial activity	Moheimani et al., 2022
Pelvetia canaliculata (Linnaeus) Decaisne and Thuret		Antileishmanial activity	Spavieri et al., 2010
Pelvetia siliquosa C.K.Tseng & C.F.Chang	Phlorotannin	Anti-diabetuc	Lee et al., 2004
Petalonia binghamiae (J.Agardh) K.L.Vinogradova	fucoxanthin		Mori et al., 2004
Polycladia myrica (S.G.Gmelin) Draisma, Ballesteros, F.Rousseau & T.Thibau Syn: *Fucus myrica*		Antibacterial activity; antidiabetic and antioxidant activity	Pirian et al., 2017; Moheimani et al., 2022
Pylaiella littoralis (Linnaeus) Kjellman	MAAs	UV protecting; Antileishmanial	Spavieri et al., 2010
Saccharina cichorioides (Miyabe)Druehl &Saunders	Sulfated polysaccharides	anticancer activity	Vischuk et al., 2013
Saccharina japonica (Areschoug) Druehl &Saunders	Sulfated polysaccharides, Fucoidan	Antidiabetic activity; moisturizing	Wang et al., 2013
Saccharina latissima (Linnaeus) Druehl & G.W.Saunders	Sulfated galactofucan	Anti-inflammatory	Ehrig and Alban, 2015
Saccharina longicruris (Bachelot Pylaie) Kuntze	Laminaran	Skin anti-aging	Li et al., 2013
Saccorhiza polyschides (Lightf.) Batt.		Antileishmanial activity	Spavieri et al., 2010
Sargassum angustifolium C.Agardh	sulfated polysaccharides	antioxidant and antidiabetic	Borazjani et al., 2018
Sargassum aquifolium (Turner) C.Agardh	Sulfated polysaccharides	anticoagulant activity	Bilan et al., 2017
Sargassum binderi Sonder ex J.Agardh	Fucoxanthin; Fatty acids; sulfated polysaccharides	Anti-inflammatory activity	Noviendri et al., 2011
Sargassum boveanum J.Agardh	Fatty acids	Antibacterial and Antidiabetic	Pirian et al., 2020

Taxa	Medicinal effect	Active component	Reference
Sargassum cristaefolium C.Agardh	sulfated polysaccharides	Anti-inflammatory activity	Wu et la., 2016
Sargassum dentifolium (Turner) C.Agardh		Insecticidal effect	Aboutabl et al., 2002
Sargassum duplicatum (J.Agardh) J.Agardh	Fucoxanthin; Fatty acids; sulfated polysaccharides	Anti-inflammatory activity	Noviendri et al., 2011
Sargassum filipendula C.Agardh	Sulfated polysaccharides.	antioxidant and antiproliferative	Costa et al., 2010
Sargassum fluitans (Børgesen) Børgesen	Polysaccharides	antioxidant activity	Chale-Dzul et al., 2017
Sargassum fulvellum (Turner) C. Agardh	Sulfated polysaccharides	Anticoagulant, Anti-inflammatory	Monsur, et al., 2014
Sargassum fusiforme (Harvey) Setchell (Syn: *Hizikia fusiformis*)	Sulfated polysaccharides, fucosterol,phlorotannins; glycyrrhizin; fucoxanthin; fatty acids	Anticoagulant, antitumor, osteoprotective; anti diabetic; Anti- HIV; Alzheimer	Sanjeewa et al., 2018; Meinita et al., 2021
Sargassum glaucescens J.Agardh	Steroles	Antibacterial and antifungal; antidiabetic	Yegdaneh et al., 2020
Sargassum graminifolium C.Agardh	polysaccharides	Antioxidant properties	Zhang et al., 2012
Sargassum hemiphyllum (Turner) C.Agardh	Sulfated Polysaccharides	anti-inflammatory anticoagulant	Hwang et al., 2015
Sargassum henslowianum J.Agardh	Sulfated Polysaccharides; amino acids	antioxidant activity	Chem et al., 2010.
Sargassum horneri (Turner) C.Agardh	Sulfated polysaccharides	Anticancer, anti-herpes; antioxidant	Wen et al., 2016
Sargassum johanstonii Setchell & N.L.Gardner	Total steroles	Antibacterial activity	Rao et al., 1986
Sargassum kjellmanianum Yendo	Sulfated polysaccharides	Immunological and antitumor	Ma et al., 2013
Sargassum marginatum (C.Agardh) J.Agardh	Unsaturated fatty acids; Polyphenols	Antioxidant; antiaging; anticancer	Bhaskar et al., 2004
Sargassum mcclurei Setchell	Sulfated Polysaccharides: fucoidan	antiviral activity; anticancer	Thuy et al., 2015
Sargassum muticum (Yendo) Fensholt	Polysaccharides, Polyphenols	Alzeimer; antiprotozoa; antioxidant	Namvar et al., 2013
Sargassum naozhounse C.K.Tseng & Lu Baoren	alginates and fucoidan; amino acids	Anti-herpes; infections, laryngitis	Peng et al., 2012
Sargassum natans (Linnaeus) Gaillon		Antiprotozoal	Orhan et al., 2006
Sargassum oligocystum Montagne	Sterols; MAAs	UV protecting; anti-leishmanila	Fouladvan et al., 2011
Sargassum pallidum (Turner) C.Agardh	Sulfated polysaaccharides; Fatty acids	Antitumor, antimicrobial; antidiabetic	Xiao et al., 2019
Sargassum patens C.Agardh	Sulfated polysaccharides	Anti-herpes	Zhu et al., 2003
Sargassum plagiophyllum C.Agardh	Sulfated polusaccharides	Antibacterial; anticancer;antioxidant	Suresh et al., 2013
Sargassum polycystum C.Agardh	Sulfated polysaccharides	Antiviral; anti-neuroinflammatory	Aisya et al., 2014
Sargassum sagamianum Yendo	Sargaquinoic acid, Sargachromenol	Skin disease	Hur et al., 2008
Sargassum serratifolium C. Agardh	Plastoquinones	Antidiabetic, anticancer,Alzheimer	Ali et al., 2017
Sargassum siliquastrum (Mertens ex Turner) C.Agardh	fucoxanthin	Skin care; antioxidant, antimelanogenesis	Corpuz et al., 2013
Sargassum swartzii C.Agardh	Sulfated polysaccharides; phenolic compounds	Larvicidial, anti HIV-1, anticncer	Khanavi et al., 2011
Sargassum tenerrimum J.Agardh	Sulfated polysaccharides	Antioxidant, antibacterial activity	Sadati et al., 2011
Sargassum thunbergii (Mertens ex Roth) Kuntze	Phlorotannins	anticoagulant activity	Wei et al., 2008
Sargassum vulgare C.Agardh	Sulfated polysaccharides, fucans	Antidiabetic,antibacterial	Pirian et al., 2018
Sargassum wightii Greville	Lipids; sulfated polysaccharides	Antimicrobial, anticancer	Pugazhend et al., 2019
Sargassum yezoense (Yamada) Yoshida & T.Konno		Adipogenesis regulatory	Kim et al., 2008
Scytosiphon lomentaria (Lyngbye) Link	Fucoxanthin	antiprotozoa	Spavieri et al., 2010
Sirophysalis trinodis (Forsskal) Kützing	Fucoxanthin	Antioxidant and antidiabetic	Pirian et al., 2017;
Spatoglossum asperum J.Agardh	Sulfated polusaccharides	Antibacterial, antioxidant activity	Palanisamy et al., 2017
Stypocaulon scoparium (L.) Kützing		Antiprotozoal	Spavieri et al., 2010
Stypopodium zonale (J.V.Lamouroux) Papenfuss		Anti-leishmania	Soares et al., 2016
Turbinaria conoides (J.Agardh) Kützing	Sulfated Polysaccharides: Polyphenols	Antioxidant; antiaging, anticancer	Kim et al., 2018
Turbinaria decurrens Bory	Sulfated Polysaccharides.	Antioxidant, hepatoprotective	Zhong et al., 2019
Turbinaria ornata (Turner) J.Agardh	Sulfated Polysaccharides.	Antioxidant, antiviral activity	Thuy et al., 2015
Turbinaria turbinata (Linnaeus) Kuntze	Sulfated polysaccharides	Anti-inflammatory; anti-leishmania	Freile et al., 2008
Undaria pinnatifida (Harvey) Suringar	Sulfated polysaccharides, fatty acids; fucoxanthin	Antiviral, antimicrobial, anticancer	Peng et al., 2018

sp. Among the medicinal chlorophyceans *Codium fragile* is the most cited taxon with various medicinal properties. *Ulva lactuca* is another most cited taxon with various medicinal properties, additionally is an edible green alga. The active components of medicinal green algae are diverse including sulfated polysaccharides, mycosporine-like amino acids, fatty acids, various pigments and glycoproteins which, give them various antioxidant, anti-inflammatory, antibiotic, antibacterial, skin care, anti-tumor, and many other activities (Table 3). Mycosporine-like amino acids and sulfated polysaccharaids are the two main compounds reported in the literature as bioactive compounds (Figure 2). There are also alkaloids in some green algae considered as others in the Figure 2.

Cyanobacteria

Cyanobacteria are called blue-green algae, a group of bacteria that harness energy through the process of photosynthesis, absorbing the sun's energy and converting it into usable energy. They also produce a variety of toxins which are primarily neurotoxins, cytotoxins, endotoxins, or hepatotoxins. Cyanobacteria have also been identified as a potential source of renewable energy due to their ability to produce sugars and ethanol as well as agents with potentially antibiotic properties (Whitton, 2002).

As other groups above mentioned, certain cyanobacteria have been studied for their efficiency in skin care products, attributed to the UV absorbing and protective effects derived form their MAAs. *Nostoc* is a prevalent genus characterized by its filamentous thallus, which frequently forms colonies. Due to the heterocyst cells, *Nostoc* has capability of fixing the atmospheric nitrogen. *Spirulina*, which features screw-like coiled trichomes, is recognized as for its nutritional value. Additionally, among the cyanobacteriae *Lyngbya majuscules* exhibits various effects (Table 4).

Bacillariophyta

The Bacillariophyta are called the diatoms. As mentioned for brown algae, in some classifications, the diatoms are considered as a class in phylum Heterokontophyta (e.g. Lee, 2008). Diatoms, as unicellular organisms, mostly share the feature of having a cell wall composed of silicon dioxide. The cell wall of diatoms is insoluble in water, which is why the majourity inhabit the bottoms of lakes and ponds. Generally, diatoms possess two general shapes; the centric diatoms, or round, and the pennate diatoms, which are bilaterally symmetrical (Lee, 2008). There are about 15,000 distinct species of diatoms (Guiry and Guiry, 2022). Despite their vast diversity, the application of diatoms for medicinal purposes is limited in comparison to other groups, possibly due to their rigid cell wall. In the literature we reviewed, *Phaeodactylum tricornutum* emerged as the most frequently cited bacillariophycean, noted for its antibacterial, anti-inflammatory, and immunomodulatory properties. Some diatoms also exhibit UV protective effects due to their mycosporine-like amino acid compounds. Additionally, certain species serve as sources of significant fatty acids that may have potential medicinal effects in the context of heart disease (Table 4).

Other categories of algae

A small number of the medicinal algae we

Table 3. Medicinal taxa from phylum chlorophyta

Taxa	Medicinal effect	Active component	Reference
Acetabularia mediterranea J.V. Lamouroux	MAAs	UV protective effect	Sinha et al., 1998
Acrosiphonia arcta (Dillwyn) Gain	MAAs	UV protective effect	Karsten et al., 1998a
Acrosiphonia penicilliformis (Foslie) Kjellman	MAAs	UV protective effect	Karsten et al., 1998a
Anadyomene saldanhae A.B. Joly & E.C. Oliveira		Antiprotozoal	Bianco et al., 2013
Ankistrodesmus spiralis (W.B. Turner) Lemmermann	MAAs	UV protective effect	Xiong et al., 1999
Boodlea composite (Harvey) F. Brand	MAAs	UV protective effect	Karsten et al., 1998b
Botryococcus braunii Kützing	Antioxidant agent: Butylated hydoxytoluene	Antioxidant, skin angi-aging	Buono et al., 2012
Bryopsis corticulans Setchell	Lipid and protein	Edible, potential antioxidant	Pirian et al., 2020
Bryopsis plumose (Hudson) C. Agardh	Sulfated polysaccharides	Antioxidant activity	Zhang et al., 2010
Capsosiphon fulvescens (C. Agardh) Setch. & Gardner	Polysaccharides	Immunostimulating; anticancer	Na et al., 2010
Caulerpa cupressoides var. *flabellate* Borgesen	Sulfated Polysaccharides.	Antioxidant, antiprotozoal	Bianco et al., 2013
Caulerpa lentillifera J. Agardh	Sulfated Polysaccharides; alkaloid: caulerpin	Antidiabetic, antibacterial	Vairappan, 2004
Caulerpa microphysa (Weber Bosse) Feldmann	Caulerpin, phytol	Antibacterial	Vairappan, 2004
Caulerpa peltata J.V. Lamouroux		Antioxidant	Murugan et al., 2013
Caulerpa prolifera (Forsskal) J.V. Lamouroux	Sulfated Polysaccharides	Osteogenic	Cui et al., 2018
Caulerpa racemosa (Forsskal) J. Agardh	MAAs, Sulfated Polysaccharides, fatty acids;	UV protective; antiprotozoal; antitumor; Antibacterial,antiviral	Wang et al., 2007; Ji et al., 2008; Pirian et al., 2020
Caulerpa sertularioides (S.G. Gmelin) M. Howe	Sulfated polysaccharides, fatty acids	Antiprotozoal; antioxidant	Pirian et al., 2020
Caulerpa taxifolia (M.Vahl) C.Agardh	Caulerpenune	antitumor	Barbier et al., 2001
Caulerpa webbiana Montagne	MAAs	UV protective effect	Gröniger et al., 2000
Chaetoceros calcitrans (Paulsen) H. Takano	fatty acids; essential amino acids	Antioxidant activity	Natrah et al., 2007
Chaetomorpha aerea (Dillwyn) Collins	MAAs	UV protective	Karsten et al., 1998a
Chaetomorpha antennina (Bory) Kutzing	Sulfated polysaccharides	Antibacterial and antioxidant	Thanigaivel et al., 2014
Chaetomorpha brachygona Harvey	Fatty acids	Anticancer, antioxidant activity	Majumder et al., 2020
Chaetomorpha tortuosa Kutzing	MAAs	UV protective	Karsten et al., 1998a
Chlamydomonas nivalis (F.A. Bauer) Wille	Phenolic compounds	Antimicrobial; UV protective	Duval et al., 2000
Chlorella luteoviridis Chodat	MAAs	UV protective	Karsten et al., 2007
Chlorella minutissima Fott & Novakova	Fatty acid: EPA, DHA; MAAs	heart disease; UV protecting	Xiong et al., 1999
Chlorella pyrenoidosa H. Chick	Polysaccharides	Antitumor, immunostimulatory	Pugh et al., 2001
Chlorella sorokiniana Shihira & R.W. Krauss	MAAs, carotenoids, α-tocopherol	Antioxidant, UV protective	Hidalgo et al., 2014
Chlorella sp.	MAAs	UV protective effect	Xiong et al., 1997
Chlorella stigmatophora Butcher	Polysaccharide	Anti-inflammatory	Guzman et al., 2003
Chlorella vulgaris Beijerinck	Glycoprotein	Anti-skin cancer; Dermatitis; antimetastatic; antitumor	Singh et al., 1999; Kang et al., 2015
Chlorococcum sp.	Linolenic acid	Antibiotic effect	Ohta et al., 1995
Cladophora glomerata (Linnaeus) Kutzing	Sulfated polysaccharides	Immunomodulatory activity	Surayot et al., 2016
Cladophora rupestris (Linnaeus) Kutzing	MAAs	UV protctive effect; antiprotozoa	Spavieri et al., 2010
Codium adhaerens C. Agardh	MAAs	UV protctive effect	Sinha et al., 1998
Codium bursa (Linnaeus) C. Agardh		antiprotozoa	Süzgeç-Selçu et al., 2011
Codium divaricatum (C. Agardh) Baisoletto	Sulfated Polysaccharides	anticoagulant activity	Li et al., 2015

Taxa	Medicinal effect	Active component	Reference
Codium fragile (Suringar) Hariot	Sulfated Polysaccharides; MAAs	Antidiabetic; skincare; anti-edema, antiallergic; anti cancer	Kolsi et al., 2018; Wang et al., 2022.
Coelastrella striolata var. *multistriata* (Tren.) Kal. & Pun.	canthaxanthin, astaxanthin, β-carotene	Antioxidant	Abe et al., 2007
Dictyosphaeria cavernosa (Forsskal) Borgesen	MAAs	UV protective effect	Karsten et al., 1998b
Dunaliella primolecta Butcher	Linolenic acid	Antibiotic effect	Ohta et al., 1995
Dunaliella tertiolecta Butcher	MAAs	UV protecting	Hannach and Sigleo., 1998
Enallax coelastroides (Bohlin) Skuja	MAAs	UV protective effect	Xiong et al., 1997
Gayralia oxysperma (Kutzing) K. L. ex Scagel & al.	Sulphated Polysaccharides	anticancer activity	Ropellato et al., 2015
Haematococcus pluvialis Flotow	Carotenoids: Astaxanthin; fatty acids	Antioxidant; antitumor, UV protect	Ceron et al., 2007
Halimeda cuneata Hering		Acetylcholinesterase inhibitory	Rengasamy et al., 2015
Halimeda opuntia (Linnaeus) J. V. Lamouroux		Antileishmania	García Parra et al., 2012
Halimeda tuna (J. Ellis & Solander) J. V. Lamouroux		Antioxidant activity	Taheri et al., 2017
Lola implexa (Dillwyn) Hamel		Skin anti-aging	Xhauflaire et al., 2008
Monostroma angicava Kjellman	Sulfated Polysaccharides	Anticoagulant, antidiabetic	Li et al., 2017
Monostroma hariotii Gain	MAAs	UV Protective	Hoyer et al., 2001
Monostroma latissimum Wittrock	Sulfated Polysaccharides	antiviral activity	Wang et al., 2018
Monostroma oxyspermum (Kutzing) Doty	Sulfated Polysaccharides	Anticoagulant, antioxidant	Seedevi et al., 2015
Nannochloris sp.	Fatty acid: EPA, DHA	anti-inflammatory, heart disease	Youngmanitchai, 1989
Oedogonium intermedium Wittrock ex Hirn	Carotenoides	Antioxidant, antidiabetic	Wang et al., 2017
Penicillus capitatus Lamarck	Sulfated Polysaccharides	anticoagulant activity	Arata et al., 2015
Prasiola crispa ssp. *antarctica* (Kutzing) Knebel	MAAs	UV protecting	Hoyer et al., 2001
Prasiola stipitata Suhr ex Jessen	MAAs	UV protecting	Gröniger and Häder, 2002
Pseudococcomyxa sp.	MAAs	UV protective effect	Xiong et al., 1997
Pyramimonas parkeae R. E. Norris & B. R. Pearso	MAAs	UV protecting	Hannach and Sigleo., 1998
Scenedesmus sp.	MAAs	UV protective effect	Xiong et al., 1997, 1999
Scotiella chlorelloidea J. W. G. Lund	MAAs	UV protective effect	Xiong et al., 1997
Ulva armoricana Dion, Reviers & Coat	Sulfated Polysaccharides	Anticoagulant, antibacterial	Massironi et al., 2019
Ulva californica Wille	Fatty acids	Antioxidant activity	Pirian et al., 2016
Ulva chaugulii M.G.Kavale & M.A.Kazi	Essential amino acids and fatty acids	edible	Pirian et al., 2018
Ulva compressa Linnaeus	Fatty acids	Antiallergic, anti-anaphylactic	Shabab et al., 2011
Ulva conglobate Kjellman		anti-neuroinflammatory	Jin et al., 2006
Ulva fasciata S.F. Gray	Sulfated Polysaccharides	Anti-cancer, antidiabetic	Shao et al., 2013b
Ulva flexuosa Wulfen Syn: *Enteromorpha flexuosa*	Phenols and flavonoids	Antioxidant activity	Gazali et al., 2021
Ulva intestinalis (Linnaeus) Syn: *Enteromorpha intestinalis*	Sulfated Polysaccharides, MAAs	UV protecti; antileishmania	Tabarsa et al., 2018
Ulva lactuca Linnaeus	Sulfated polysaccharides; MAAs	Skin hydrating, antibacterial	Ghareeb et al., 2021
Ulva linza Linnaeus Syn: *Enteromorpha linza*	Sulfated Polysaccharides; phenolics and flavonoids;	Anticoagulant, antioxidant activity; antibacterial activity	Wang et al., 2013; Arman et al., 2015;
Ulva ohnoi Hiraoka & S.Shimada	Essential amino acids and fatty acids		Pirian et al., 2018
Ulva pertusa Kjellman	Sulfated polysaccharides, Ulvans	antioxidant activity	Zhang et al., 2010
Ulva prolifera O. F. Muller Syn: *Enteromorpha prolifera*	Sulphated Polysaccharides	Antioxidant, antihyperlipidemic	Ren et al., 2018
Ulva rigida C. Agardh	Sulfated Polysaccharides	Antibacterial, anticoagulant	Tziveleka et al., 2018
Ulva sp.	Sulfated Polysaccharides, Ulvans	Skin protective; Skin anti-aging	Adrien et al., 2017
Undaria pinnatifida (Harvey) Suringar	Sulfated Polysaccharides	antioxidant activity	Hu et al., 2010
Valonia aegagropila C. Agardh	MAAs	UV protective	Karsten et al., 1998b

Table 4. Medicinal taxa from other phylla

Taxa	Medicinal effect	Active component	Reference
Bacillariophyta			
Asterionella japonica Cleve	Fatty acid: EPA, DHA	anti-inflammatory heart disease	Youngmanitchai, 1989
Biddulphia sinensis Greville	Fatty acid: EPA, DHA	anti-inflammatory; heart disease	Youngmanitchai, 1989
Chaetoceros sp.	MAAs	UV protective	Riegger &Robinson, 1997
Corethron criophilum Castracane	MAAs	UV protective effect	Helbling et al., 1996
Coscinodiscus centralis Ehrenberg	MAAs	UV protecting	Riegger & Robinson, 1997
Cylindrotheca fusiformis Reimann & J.C.Lewin	Fatty acid: EPA, DHA	anti-inflammatory, heart disease	Tan and Johns, 1996
Fragilariopsis cylindrus (Grun ex Cleve) Helm &Krieger	MAAs	UV protecting	Riegger & Robinson, 1997
Navicula incerta Ehrenberg	Fatty acid: EPA, DHA	anti-inflammatory; heart disease	Tan and Johns, 1996
Navicula saprophila Lange-Bertalot & Bonik	Fatty acid: EPA, DHA	anti-inflammatory, heart disease	Kitano et al., 1997
Nitzschia frustulum (Kutzing) Grunow	Fatty acid: EPA, DHA	anti-inflammatory; heart disease	Renaud et al., 1994
Nitzschia laevis Hustedt	Fatty acid: EPA, DHA	anti-inflammatory; heart disease	Wen and Chen, 2002
Odontella aurita (Lyngbye) C.Agardh	Fucoxanthin	Antioxidant	Xia et al., 2013
Phaeodactylum tricornutum Bohlin	Fatty acid: EPA; DHA	Antibacterial; anti-inflammatory	Guzman et al., 2003
Proboscia inermis (Castracane) R.W.Jordan & Ligowski	MAAs	UV protecting	Riegger &Robinson, 1997
Porosira glacialis (Grunow) Jørgensen	MAAs	UV protective	Riegger &Robinson, 1997
Porosira pseudodenticulata (Hustedt) Jousé	MAAs	UV protective	Riegger & Robinson, 1997
Pseudonitzschia sp.	MAAs	UV protecting	Helbling et al., 1996
Stellarima microtrias (Ehrenberg) G.R.Hasle & P.A.Sims	MAAs	UV protecting	Riegger & Robinson, 1997
Thalassiosira sp.	MAAs	UV protective effect	Helbling et al., 1996
Thalassiosira tumida (Janisch) Hasle	MAAs	UV protecting	Riegger & Robinson, 1997
Thalassiosira weissflogii (Grunow) G.A. Fryxell & Hasle	MAAs	UV protecting	Hannach and Sigleo., 1998
Cyanobacteriae			
Anabaena sp.	MAAs	UV absorbing, skin care	Sinha et al., 1998
Aphanizomenon flos-aquae Ralfs ex Bornet & Flahault	Phycocyanin, Lipopeptide, Polysaccharide	Antioxidant; antibiotic, anticancer	Pugh et al., 2001
Aphanocapsa sp.	MAAs	UV protecting	Gröniger et al., 2000
Aulosira fertilissima S.L.Ghose	Aromatic	Anticancer	Burja et al., 2001
Calothrix crustacean Thuret ex Bornet & Flahault	MAAs	UV protecting	Garcial and Casten, 1991
Calothrix parietina Thuret ex Bornet & Flahault	MAAs	UV protecting	Garcia and Castenh, 1993
Calothrix sp.	Scytonemin, MAAs	UV absorbing, skin care	Brenowitz and Caste,1997
Calothrix sp.	Calothrix A & B	Antimalaria, anticancer	Rickards et al., 1999
Chlorogloeopsis sp.	Scytonemin	UV absorbing, skin care	Garcia-Pichel et al., 1992
Chroococcidiopsis sp.	MAAs	UV protecting	Dilion and Castenh, 1999
Chroococcus sp.	MAAs	UV protecting	Garcia and Casten, 1991
Chrysocapsa sp.	MAAs	UV protecting	Turin, 1985
Cylindrospermopsis raciborskii (Wołos.) Seen. & Subba.	Antioxidant agent: Butylated hydroxytoluene	Antioxidant	Babu and Wu, 2008
Cylindrospermum licheniforme Kützing & Flahault	Alkaloids	Anticancer, cytotoxic	Burja et al., 2001
Diplocolon sp.	MAAs	UV protecting	Garcia-Pichel et al., 1991
Entophysalis granulosa Kützing	MAAs	UV absorbant	Garcia and Casten, 1991
Fischerella muscicola Gomont	Lipopeptide	Antifungal, herbicidal	Burja et al., 2001
Gloeocapsa sp.	MAAs	UV absorbing, skin care	Sommaruga& Garcia 1999
Hapalosiphon fontinalis Bornet	Alkaloids, indoles	Antibiotic, antifungal	Burja et al., 2001

Taxa	Medicinal effect	Active component	Reference
Hapalosiphon sp.	MAAs	UV protective	Garcia and Castehol, 1991
Hapalosiphon welwitschii West & G.S.West	Alkaloids, lipopeptide	Anticancer, antibiotic, antimitotic	Burja et al., 2001
Hormothamnion enteromorphoides Grunow & Flahault	Lipopeptide	Antibiotic, cytotoxicity	Burja et al., 2001
Hyella caespitosa Bornet & Flahault	Alkaloides	Antifungal	Burja et al. 2001
Lyngbya aestuarii Liebman ex Gomont	MAAs	UV protective	Robbins et al., 1998;
Lyngbya confervoides C.Agardh ex Gomont	Lipopeptides: obyanamide, Lobocyclamides	Antitumor, anticancer	Tan, 2007
Lyngbya lagerheimii (Gomont) Anagnostidis & Komárek	Fatty acid,	Anti-HIV activity	Burja et al., 2001
Lyngbya majuscule Harvey ex Gomont	Lipopeptides; tryptophan derivative; quinolone alkaloid, amide, amine, imidazole	Anticancer, antitumor, antifungal, antimicrobial; antiviral, anti-HIV	Tan, 2007; Burja et al., 2001
Lyngbya sp.	Scytonemin, MAAs	UV absorbing, skin care	Proteau et al., 1993
Microcoleus chthonoplastes Thuret ex Gomont	Carotenoides and MAAs	UV absorbing, skin care	Karsten et al., 1998
Microcoleus paludosus Gomont	MAAs	UV protective	Karsten and Garcia, 1996
Microcystis aeruginosa (Kützing) Kützing	Lipopeptide; butylated hydroxytoluene	Anticancer, antibiotic, antioxidant	Burja et al., 2001
Nostoc commune Vaucher ex Bornet & Flahault	MAAs, UV absorbing pigment, lipopeptide, terpene	Ultraviolet A/B sunscreen, antifungal, antibiotic, anticancer	Ehling Schulz et al., 1997, Burja et al., 2001
Nostoc ellipsosporum Rabenhorst ex Bornet & Flahault	Peptides and proteins	Anti-HIV, antiviral	Burja et al., 2001
Nostoc microscopicum Carmichael ex Bornet & Flahault	MAAs	UV protecting	Garcia and Casten, 1991
Nostoc muscorum (Born & Flahault) Hrouzek & Ventura	Lipopeptide	Antibiotic	Burja et al., 2001
Nostoc parmelioides Kützing ex Bornet & Flahault	MAAs	UV protecting	Garcia and Castenh, 1991
Nostoc pruniforme C.Agardh ex Bornet & Flahault	MAAs	UV protecting	Garcia and Casten, 1991
Nostoc sphaericum Vaucher ex Bornet & Flahault	Indoles	Antiviral	Burja et al., 2001
Nostoc spongiaeforme C.Agardh ex Bornet & Flahault	Pigment; MAAs; Lipopeptide	UV-B protect, antibiotic, antialgal	Burja et al., 2001
Oscillatoria acutissima Kufferath	Ketals, lactons	Anticancer	Burja et al., 2001
Oscillatoria nigroviridis Thwaites ex Gomont	Aromatic, bromo- Lipopeptie	Anticancer	Burja et al., 2001
Oscillatoria priestleyi West & G.S.West	MAAs	UV protecting	Quesada and Vincet, 1997
Oscillatoria sp.	Antioxidant agent: butylated hydroxytoluene	Antioxidant	Babu and Wu, 2008
Phormidium ectocarpi Gomont	Phenol derivatives	Antiplasmodial, antibiotic	Burja et al., 2001
Phormidium tenue Gomont	Fatty acid	Anti-HIV activity	
Pleurocapsa sp.	MAAs	UV protecting	Garcia and Castenh, 1991
Rivularia atra Roth ex Bornet & Flahault	MAAs	UV protecting	Garcia and Casten, 1991
Rivularia firma Womersley	Indoles, bromo	Anti-inflammatory	Burja et al., 2001
Rivularia sp.	Scytonemin; MAAs	UV absorbing, skin care	Garcia and Casten, 1991
Schizothrix calcicola Gomont	Indol, Aromatic, bromo	Antibiotic, anticancer	Burja et al., 2001
Schizothrix sp.	MAAs	UV protecting	Garcia and Castenh, 1991
Scytonema hofmanii C.Agardh ex Bornet & Flahault	Pigment	UV-B protecting effect	Rupali & Sharma, 2021
Scytonema javanicum Bornet ex Bornet & Flahault	MAAs	UV protecting	Garcia and Casten, 1993
Scytonema mirabile Wolle	Alkaloids	Antibiotic, cytotoxicity	Burja et al., 2001
Scytonema myochrous C.Agardh ex Bornet & Flahault	MAAs	UV protecting	Pentecost, 1993
Scytonema pseudohofmanni Bharadwaja	Lipopeptide	Antifungal, antiviral, antimitotic	Burja et al., 2001
Scytonema sp.	MAAS, Scytonemin	UV absorbing, skin care	Asencio et al., 2011
Spirulina maxima (Setchell & N.L.Gardner) Geitler	Polysaccharids, amino acids, fatty acids.	Skin anti-aging; anti fatty liver	Gonzalez et al., 1993
Spirulina platensis (Gomont) Geitler	Polysaccharids, trace elements, amino acids, fatty acids.	anticancer, anti-HI, free-radical scavenger, antioxidant	Ortega-Calvo et al., 1993; Burja et al., 2001; Pugh et al., 2001
Stigonema dendroideum Frémy	Lipopeptide	Antibiotic, cytotoxic	Burja et al., 2001

Taxa	Medicinal effect	Active component	Reference
Stigonema sp.	MAAs	UV protecting	Proteau et al., 1993
Symploca hydnoides Kützing ex Gomont	Lipopeptides	Anticancer, antitumor	Tan, 2007
Synechococcus sp.	MAAs	UV protecting	Garcial and Casten, 1993
Synechococcus sp.	Lipopeptide	Antibiotic	Burja et al., 2001
Synechocystis trididemni F.Lafargue & G.Duclaux	Lipopeptide	Anticancer, antiviral,	Burja et al., 2001
Tolypothrix byssoidea Kirchner	MAAs	UV protecting	Adhikary and Sahu, 1998
Tolypothrix conglutinata Borzì ex Bornet & Flahault	Polyols, isotactic alkenes, lactones	Anticancer, cytotoxicity	Burja et al., 2001
Tolypothrix distorta Kützing ex Bornet & Flahault	MAAs	UV protecting	Garcia and Castenh, 1991
Tolypothrix nodosa Bharadwaya	Pyrrole	Antibiotic	Burja et al., 2001
Tolypothrix rupestris Wolle	MAAs	UV protecting	Garcia and Casten, 1991
Tolypothrix sp.	MAAs	UV protecting	Garcia and Casten, 1991
Tolypothrix tenuis Kützing ex Bornet & Flahault	Nucleosides	Antifungal, cytotoxic	Burja et al., 2001
Dinoflagellata			
Alexandrium excavatum (Braarud) Balech & Tangen	MAAs	UV protective effect	Carreto et al., 1990
Amphidinium carterae Hulburt	MAAs	UV protective effect	Hannach and Sigleo., 1998
Dinophysis spp		schizophrenia	He et al. 2005
Gyrodinium dorsum Kofoid & Swezy	MAAs	UV protective effect	Gröniger et al., 2000
Heterocapsa triquetra (Ehrenberg) F.Stein	MAAs	UV protective effect	Wängberg et al., 1997
Lingulodinium polyedra (F.Stein) J.D.Dodge	MAAs	UV protective effect	Vernet& Whitehead., 1996
Prorocentrum micans Ehrenberg	MAAs	UV protective effect	Carreto et al., 1989
Prorocentrum minimum (Pavillard) J.Schiller	MAAs	UV protective effect	Sinha et al., 1998
Haptophyta			
Cricosphaera carterae (Braarud & Fagerland) Braarud	Fatty acid: EPA, DHA	anti-inflammatory; heart disease	Youngmanitchai, 1989
Cricosphaera elongata (Droop) Braarud	Fatty acid: EPA; DHA	anti-inflammatory; heart disease	Youngmanitchai, 1989
Isochrysis galbana Parke	Fatty acids: EPA, DHA	anti-inflammatory; heart disease	Natrah et al., 2007
Isochrysis sp.	MAAs	UV protecting	Hannach and Sigleo., 1998
Pavlova gyrans Butcher	MAAs	UV protecting	Hannach and Sigleo., 1998
Pavlova lutheri (Droop) J.C.Green	Fatty acids: EPA, DHA.	anti-inflammatory; heart disease	Volkman et al., 1991
Pavlova salina (N.Carter) J.C.Green	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Volkman et al., 1991
Pavlova spp.	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Volkman et al., 1991
Phaeocystis antarctica Karsten	MAAs	UV protecting	Riegger & Robinson, 1997
Phaeocystis pouchetii (Hariot) Lagerheim	MAAs	UV protective effect	Marchant et al., 1991
Ochrophyta (Chrysophyceae)			
Monochrysis lutheri Droop	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Youngmanitchai, 1989
Ochrophyta (Dictyochophyceae)			
Pseudopedinella sp.	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Youngmanitchai, 1989
Ochrophyta (Eustigmatophyceae)			
Nannochloropsis sp	Mycosporine-like amino acids	UV-screening agent; Sunscreen	Chu 2012
Nannochloropsis sp.	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Youngmanitchai, 1989
Ochrophyta (Xanthophyceae)			
Monodus subterraneus J.B.Petersen	Fatty acid: EPA, DHA.	anti-inflammatory; heart disease	Qiang et al., 1997
Heterococcus brevicellularis Vischer	MAAs	UV protective effect	Xiong et al., 1997

reviewed, belong to the other groups of algae including dinoflagellates and Haptophyta. Xanthophyceae, Eustigmatophyceae, Dictyochophyceae and Chrysophyceae also include representatives. The active components of these categories were primarily fatty acids and MAAs (Table 4).

Conclusion

Algae possess a wide range of applications in pharmacology, health related products, cosmetic and food production. The large number of the taxa we reviewed belonged to the Rhodophyta (red algae), Phaeophyta (brown algae) and Chlorophyta (green algae) which are mostly macroalgae. Based on the literature we reviewed, carbohyderates are identified as the main active compounds in brown algae, while in red and green algae both proteins and carbohydrates play a significant role. Furthermore, in brown and red algae the fatty acids have less portion than the green algae and among these three phyla, phlorotanins were only reported in brown algae. The medicinal application of algae encompasses a range from antibacterial and antiprotozoal activities, as well as treatments for cancer, diabetes and other chronic conditions including heart disease and Alzheimer. Many of these organisms possess potential of using in skin care products due to their UV protecting ability. However, the application of algae extracts for certain specific disease is currently undergoing phase of laberatoray investigations, and additional clinical trials are rquired to confirm their effectiveness in human disease. On the other hand, it is essential to identify and establish optimal growth conditions for each taxon which may present cost-related-challenges. Moreover, harvesting from natural habitats may lead to environmental crisis. Additionally, various factors influence the chemical content of algae including species, season, age, geographical location and environmental conditions. In this review, we have documented 496 taxa with medicinal applications sourced from literature, however this represents only a small part of the extensive diversity of algae. Further research is required to extract additional compounds from various taxa and assess their biological activities both *in vitro* and *in vivo*.

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