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Algae as an Important Resource of Natural Products of Medical and Biotechnological Importance: A Mini-Review

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ABSTRACT

Algae are typically aquatic chlorophyll-containing organisms comprised of unicellular microscopic forms as well as large macroscopic entities such as seaweeds. The biomasses derived from algae are potential sources of bioactive compounds, biofuels and food-based products. Most of the biologically active products obtained from algae are used in pharmaceutical, food, agricultural and energy industries. Several natural products such as polyphenols, sterols, polyunsaturated fatty acids, proteins, sulphated polysaccharides, alkaloids, alginic acid, and carotenoids have been identified and isolated from some species of macroalgae and microalgae, and have found great application in biotechnology, medicine, human and animal nutrition. Despite several reports on the biological activities of natural products from algae and their application as functional foods as well as in renewable energy, many species of macroalgae and microalgae are yet to be explored. Future research may focus on identification of new species and their novel bioactive products and application in the food, pharmaceutical, agricultural and energy industries. Hence, this paper highlights the usefulness of algae as a reservoir of natural products in biotechnology and medicine.

Keywords: *Microalgae, Macroalgae, Biotechnology, Health, Natural products.*

Introduction

Algae represents a very large and distinct group of organisms that exist in the aquatic environment. These organisms have plant-like structures that are devoid of vascular systems including seaweeds with undifferentiated cells. Algae have tremendous ecological importance because it constitutes a very large proportion of the world's biodiversity and supplies oxygen to the aquatic habitat thereby acting as a major primary producer in the marine food chain.[1] Algae are one of the richest and promising reservoirs of natural products. Previous report has shown that about 9% of biologically active compounds from marine organisms are present in algae.[2] Many species of algae thrive in extreme environmental conditions and have developed survival mechanisms, which lead to the release of unique primary and secondary metabolites that are absent in terrestrial plants.[3] Also, up to 50% of drugs approved by the Food and Drug Administration (FDA) in the United States consists of secondary metabolites derived from marine organisms and their synthetic analogs[4] and about 30 % of these metabolites are obtained from algae. Propylene glycol alginate sodium sulphate is an anti-angiocardiopathy drug produced from marine algae which are clinically used for the treatment of heart and brain diseases.[4] Apart from the pharmaceutical application of alga; they have great potential application in the food and cosmetic industries. Some seaweeds (red, green and brown macroalgae) are consumed as functional foods due to their nutritional quality and health-promoting effects which are attributed to the presence of vitamins, minerals as well as bioactive substances such as polyunsaturated fatty acids, sterols, polysaccharides, polyphenols and proteins.[5] The world of algae appears to be a promising source for novel antimicrobial, neuroprotective, antidiabetic and antihypertensive agents as well as food bioproducts, agricultural products and biofuels. This has brought a great interest in the exploration of different species of macroalgae and microalgae for novel compounds, functional foods, dietary supplements as well as agro-products and biofuels.

Algal natural products

Research in the potential use of algae for the treatment and/or prevention of degenerative diseases has gained much interest over the years. Macroalgae have been used in traditional medicine for the treatment of wounds, cough, asthma, goiter, haemorrhoids, fever, stomachache, headache and infections.[6,7] Furthermore, extracts and their fractions derived from algae have been reported to exhibit several biological activities including antidiabetic, antihypertensive, anti-inflammatory,[4] trypanocidal, leishmanicidal,[7] antioxidant and neuroprotective activities.[3] These have been attributed to some chemical compounds present in the algae. Guedes *et al*.,[8] reported the anticancer activity of different solvent extracts of green algae (*Ulva lactuca*), red algae (*Digela simplex, Hypnea musciformis* and *Gracilaria caudata*) and brown algae (*Sargassum vulgare, Padina gymnospora* and *Dictyota dichotoma*). Phlorotannins are polyphenols which are commonly found in algae, largely brown algae, comprised of phloroglucinol units. They are used as active ingredients in nutraceuticals.[9] Some phlorotannins such as dieckol, 7-phloroeckol, eckol and phloroglucinol exhibit antidiabetic activity via inhibition of α-glucosidase and protein tyrosine phosphatase-1B inhibition.[10] Furthermore, a phlorotannin known as dioxinodehydroeckol was isolated from *Ecklonia bicyclis*. This compound exhibited neuroprotective activity by reducing the activity of *β*-secretase- a major biomarker which has been implicated in Alzheimer's disease. Fucoidan, a sulphated polysaccharide

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isolated from brown algae inhibited β-amyloid induced neurotoxicity in neuronal cells and reduced caspase activity in rats.[11] Similarly, an acidic oligosaccharide sugar chain (AOSC) inhibited the formation of *β*-amyloid induced fibrils and increased cell viability in primary cortical neurons.[12] Sterols [(23E)-3*β*-hydroxystigmasta-5,23-dien-28-one and (22E)-3*β*-hydroxycholesta-5,22-dien-24-one], bisindole alkaloids (Racemosa A and Racemosa B) and terpenoids (*α*-tocospirone) increased the viability of SH-SY5Y cells.[13]

Algae as functional foods, dietary supplements and industrial products

It has been established that components from algae may provide health benefits. Several species of macroalgae and microalgae are consumed as food and used as food ingredients and supplements. Microalgae are commercially sold in form of capsules, tablets and liquid products and could be incorporated into pasta, beverages, snack foods and gums.[13] Also, microalgae have been identified as rich sources of vitamins including vitamins C, E and A as well as the B vitamins. Carotenoids such as β-carotene, lutein, astaxanthin and fucoxanthin obtained from *Dunaliela salina Chlorella vulgaris*, *Heamatococcus pluvialis* and *Sarcina maxima* are capable of exhibiting antioxidant, neuroprotective, anti-inflammatory and antidiabetic activities.[9,14] Polysaccharides such as fucans and fucanoids isolated from brown algae are used as nutritional supplements due to their health benefits such as antiproliferative, anti-inflammatory, anti-coagulant and anti-viral agents.[9] Carrageenans obtained from *B. gelatinum, E. denticulatum* and *K. alvarezii* is used for gel formation, as coatings and stabilizing agents in the meat and dairy industry. Food applications of κ- and ι-carrageenans can be seen in milk products, jams and gels. Carrageenan is known to exhibit anticoagulant, immunomodulatory, antitumour and anti-HIV activities.[15] Also, Freile-Pelegrin and Murano,[16] reported that agar produced from *Gracilaria crassissima, Gracilaria blodgettii* and *Gracilaria cervicornis could be exploited as a source of commercial grade agar.*

Algae as a resource in bio-energy

Algal biomasses are potential sources of biofuels and bioproducts and have been reported to have a number of advantages over conventional energy crops.[17] Some species of microalgae photosynthesize and multiply at a higher rate with high accumulation of metabolic products.[17] Furthermore, some species of microalgae can produce up to 70% of lipids which are useful as biofuels, with concurrent production of some biorefinery products such as fertilizers, glycerin as well as other bioproducts such as polyunsaturated fatty acids, lectins, alginate, and carotenoids. Also, most green microalgae, such as *Chlorella* spp., *Nannochloropsis oculata, Heamatococcus pluvialis*, *Spirulina platensis, Tetraselmis suecica* are used for the production of biodiesel. Apart from the cultivation of microalgae for biofuel production, heterotrophic species are able to digest organic materials in wastewaters and utilize their nutrients especially nitrogen and phosphorus.[18] Current algal research emphases involve the use of algal biomass for the production of biofuel and treatment of wastewaters contaminated with industrial, agricultural and municipal wastes.[17,19,20]

There are indications that anaerobic digestion of seaweeds gives a high yield of methane gas depending on the species and seasonal variation. Zhou *et al*.[21] reported the production of bio-oil from *Enteromorpha prolifera* via hydrothermal liquefaction in a bioreactor at high temperatures (220-320^{o}C). Recent reports in the literature suggest increasing interests in the use

of macroalgae as new biomass resources and stable feedstock for the production of bioethanol.[22,23] Despite the abundant reports on algal bioactive compounds, several species of microalgae and macroalgae are yet to be explored or even identified, and we conclude that more sustained exploration of algal biodiversity of all niches, including extreme environments, is imperative to unravel what promise to be invaluable treasures of new natural products of medical and biotechnological importance.

Conclusion

Algae are reservoirs of natural products that are produced due to their adaptive mechanism to the harsh environment where they thrive. Some of these natural products include phlorotannins, alkaloids, sterols, polyunsaturated fatty acids, carotenoids, bioactive peptides and sulfated polysaccharides. These compounds exhibit several biological activities including anti-inflammatory, antidiabetic, antioxidant, antitumour, anti-hypertensive and neuroprotective activities. The potent biological activities of these secondary metabolites have increased their exploration for novel drugs which has gained much interest over the years, and same form their application in food industries to produce functional foods, dietary supplements, nutraceuticals, preservatives and stabilizers. Furthermore, algae are being explored in biotechnology as an important resource and feedstock to produce biofuels and biorefinery products. Moreover, use of algal biomass as feedstocks could reduce the pressure on the use of green plants for the production of bioethanol. Algae therefore hold immense promise as worthy candidates of pharmaceutical and biotechnological importance. of algae.

Conflict of interest

The authors declare no conflict of interest.

Authors' declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

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