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Advances in Applied Science Research, 2016, 7(4):153-158

ISSN: 0976-8610
CODEN (USA): AASRFC

Bioactive compounds from Microalgae and its different applications- a review

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ABSTRACT

Microalgae are capable producers of food, feed supplement, chemicals, and biofuels. Marine microalgae and cyanobacteria are rich in several chemical compounds therefore, they could be used in some biological applications related with health benefits. Through microalgae, a wide variety of compounds such as polyphenols, polyunsaturated fatty acids (PUFA), or phytosterols can be obtained. However, unexplored natural sources of bioactive ingredients are gaining much attention since they can lead to the discovery of new compounds or bioactivities. This review brings the bioactive compounds produced by different microalgae, which have wide range of application in Textile industries, Pharmaceutical industries, Food industries and Petrochemical industries.

Keywords: Microalgae, Bioactive compounds, Toxins, Biofuel, environment

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INTRODUCTION

Microalgae are a huge group of photoautotrophic microorganisms, including species from different phyla such as Cyanophyta (bluegreen algae, cyanoprokaryotes, cyanobacteria), Chlorophyta (green algae), Rhodophyta (red algae), Cryptophyta, Haptophyta, Pyrrophyta, Streptophyta, Heterokontophyta. Microalgae displays a significant ecological plasticity, by the ability to adapt to changing extreme environmental conditions such as temperature, light, pH ,salinity and moisture, which describes their worldwide distribution [1-2].

Microalgae are a diverse group of photosynthetic microorganisms that convert carbon dioxide into valuable compounds including biologically active compounds such as biofuels, foods, feed and pharmaceuticals [3]. Algae are considered as a sustainable source of biodiesel which have the ability to synthesize and accumulate significant quantities of lipids as they are sunlight driven oil factories[4]. Earlier researches have shown that, compared to oil crops microalgae have 20–40 times more productivity [5] whereas some of them can accumulate up to 80% of dry lipid biomass weight . Hence, microalgae have greater potential to be a major source for renewable energy production in terms of biofuel [5,6]. Many algal strains are able to accumulate lipids when they are subjected to stress these strains have the potential to grow in mass culture [7].

Carotenoids

In photosynthetic organisms, including algae and plants, during the light phase of photosynthesis carotenoids act as accessory pigments in light harvesting and are also able to photoprotect the photosynthetic machinery from surplus light by scavenging reactive oxygen species with singlet oxygen and other free radicals [8]. Almost all carotenoids are involved in quenching singlet oxygen and trapping peroxyl radicals [9]. The bioactivities of astaxanthin including UV-light protection and anti-inflammatory activity have been reported to effect human health conditions because of their stronger antioxidant activity [10]. The wide use of carotenoids as colorants has been found in natural foods including egg yolk, chicken, and fish. More than 750 carotenoids have been identified; still, only a few have been used commercially available such as astaxanthin, canthaxanthin, lutein, lycopene and β carotene are the most common [11]. As many other antioxidant compounds are present in algal cells, the main advantages of the using microalgae as a carrier of carotenoids is their positive impact on human health. Astaxanthin is synthesized by Chlorophyceae family namely Chlorella, Chlamydomonas, Dunaliella , and Haematococcus spp., etc,.[12]. Though, a few green microalgae such as Haematococcus sp. can accumulate xanthophylls in oil bodies outside the plastids in the cytoplasm [13,14]. Formation of xanthophylls in algal cells can be influenced by nitrogen-limitation, temperature, oxidation, light intensity , metal ions and salts [15,16).

β-carotene

β-Carotene is a provitamin A carotenoid and therefore is able to be converted into retinol. Vitamin A has been revealed to reduce the risk of macular degeneration (17,18). Proposed mechanisms of action for β-carotene in cancer prevention include inhibiting the growth of cancer, induction of differentiation by modulation of cell cycle regulatory proteins, modifications in insulin like growth factor-1, hindrance of oxidative DNA damage, and possible augmentation of carcinogen-metabolizing enzymes [19]. Explicitly, β-carotene has been shown to condense cell growth and induce apoptosis in a variety of cancer cell lines, maybe through caveolin-1 expression.

Lycopene

Referred as a non-provitamin A carotenoid, lycopene possesses a variety of biological activities. These include antioxidant activity via singlet oxygen quenching and peroxyl radical scavenging, cancer prevention through inhibition of cancer growth, and induction of differentiation by modulation of cell cycle regulatory proteins. Additional reported properties of lycopene includes alterations in insulin like growth factor-1 or vascular endothelial growth factor levels, preventing the oxidative DNA damage, and possible development of carcinogen-metabolizing enzymes, reduced risk for some types of cancers, and some cardiovascular events [20,21].

Astaxanthin

Astaxanthin, another non-provitamin A carotenoid, has recently gained attention due to its antioxidant activity and is also traditionally used to pigment the flesh of salmon and trout through dietary supplementation (Table 1). Astaxanthin scavenges free radicals, provides protection against cancer and an implicated role in inflammatory processes, ocular health, and diabetes [22]. Latest studies on astaxanthin have shown its effectiveness against colon cancer cell proliferation [23], possibly through inhibition of the cell growth and increased apoptosis of human colon cancer cells [24]. The value of the worldwide carotenoid market was found to be nearly $1.2 billion in 2010 and is planned to reach over $1.4 billion by 2018 [25]. β-Carotene has the leading share of the market. Valued at $250 million in 2007, this part is expected to be worth $309 million by 2018.

Table 1: Microalgae species with high-value compounds and its applications [6,12 , 31, 47-50].

S. No	Name of the Microalgae	Product obtained	Applications
1.	*Chlorella vulgaris*	Biomass, pigments	Health food, food supplement
2.	*Chlorella* spp., *Chlorella ellipsodea*, *Coccomyxa acidophila*	Lutein, β-carotene	Pharmaceuticals, nutrition
3.	*Coelastrella striolata var. multistriata*	Canthaxanthin, astaxanthin, β-carotene	Pharmaceuticals, nutrition, cosmetics
4.	*Crypthecodinium conhi*	Docosahexaenoic acid	Pharmaceuticals, nutrition
5.	*Diacronema vlkianum*	Fatty acids	Pharmaceuticals, nutrition
6.	*Dunaliella salina*	Carotenoids, β-carotene	Health food, food supplement, feed
7.	*Galdiera suphuraria*	Phycocyanin	Pharmaceuticals, nutrition
8.	*Haematococcus pluvialis*	Carotenoids, astaxanthin, cantaxanthin, lutein	Health food, pharmaceuticals, feed additives
9.	*Isochrysis galbana*	Fatty acids, carotenoids, fucoxanthin	Pharmaceuticals, nutrition, cosmetics, animal nutrition
10.	*Lyngbya majuscule*	Immune modulators	Pharmaceuticals, nutrition
11.	*Muriellopsis sp.*	Lutein	Pharmaceuticals, nutrition
12.	*Nannochloropsis gaditana*	Eicosapentaenoic acid	Pharmaceuticals, nutrition
13.	*Nannochloropsis* sp. *Odontella aurita*	Fatty acids	Pharmaceuticals, cosmetics, baby food
14.	*Parietochloris incise*	Arachidonic acid	Nutritional supplement
15.	*Phaedactylum tricornutum*	Lipids, eicosapentaenoic acid, fatty acids	Nutrition, fuel production
16.	*Porphyridium cruentum*	Arachidonic acid, polysaccharides	Pharmaceuticals, cosmetics, nutrition
17.	*Scenedesmus almeriensis*	Lutein, β-carotene	Pharmaceuticals, nutrition, cosmetics
18.	*Schizochytrium* sp.	Docosahexaenoic acid	Pharmaceuticals, nutrition
19.	*Spirulina platensis*	Phycocyanin, γ-Linolenic acid, biomass protein	Health food, cosmetics
20.	*Ulkenia* spp.	Docosahexaenoic acid	Pharmaceuticals, nutrition

Phycobiliproteins

Phycobiliproteins serve as accessory pigments in red algae and cyanobacteria and show valuable fluorescent properties. Some of the common phycobiliproteins include phycoerythrin (PE), phycocyanin (PC), and allophycocyanin (APC). These pigments are hetero-oligomers consisting of a grouping of subunits within producing cells (Cyanophyta) or chloroplasts (Rhodophyta) that are organized into complexes called "phycobilisomes" [26]. Phycobiliproteins have been used as natural dyes; moreover, they are extensively being used as nutraceuticals or in other biotechnological applications [27].

Secondary Metabolites with Potential Commercial Value

The ecological function of secondary metabolites in microalgae or cyanobacteria is not well understood; however, several possible roles have been intended with recent researches carried out. For example, the brevetoxins responsible for neurotoxic shellfish poisoning (NSP) are generated by marine dinoflagellates which are considered to have an ecological role as a feeding deterrent .Swimmer's itch caused by the molecule Lyngbyatoxin is thought to have an ecological role as a defense against grazing [29]. Some secondary metabolites are said to play roles in sexual communication or symbiotic signals [30]. Secondary metabolites can be represented in all classes of molecules including isoprenoids, polyketides, peptides, and macromolecules such as nucleic acids, carbohydrates, proteins, and lipids. This level of chemical diversity associates with the huge number of environments inhabited by algae and cyanobacteria. Secondary metabolites signify unique adaptations to these diverse environments. Filamentous cyanobacteria growing on a shallow tropical reef, and would expect unique chemical structures with exclusive biological properties to be produced . With more richness in chemical and biological diversity, the algae and cyanobacteria are gaining more value as commercial products. For example, the unique structures produced by algal species possess rich value as components in human food, cosmetics, and various pharmaceuticals (Figure1) (Table.1).

Polyunsaturated fatty acids (PUFA)

It is very well known that, some of the ω-3 and ω-6 fatty acids are required for humans needs but cannot synthesize this is the reason why some PUFA are called essential fatty acids. The illness , smoking or alcohol intake can cause inability to synthesize some fatty acids. Essential fatty acids, particularly ω-3 and ω-6, are important for the reliability of tissues where they are incorporated. Linoleic acid is used as formulations for treatment of skin hyperplasias . Arachidonic acid can be obtained from linoleic acid; if this does not occur either due to inability for the conversion or due to deficiency in linoleic acid, it can be considered an essential fatty acid. DHA and EPA showed an ability to reduce problems associated to cardiovascular strokes and arthritis, and also to lower hypertension. Furthermore, DHA and EPA play essential roles in lowering lipid content by reducing triglycerides , augmenting HDL levels and as anti-inflammatory agents. Although it is poorly synthesized, the breast milk contains high amount thus, newborns, fed with artificial milk, should be given ω-3 DHA as an additive [31].

Sterols

Some species of microalgae have been used for promoting growth of juveniles, especially oysters for their content in sterols. Cholesterol is rarely being found in phytoplankton species such as Chaetoceros and Skeletonema that were reported to produce up to 27.7 and 2.0 µg sterols/g dry weight cholesterol being the major sterol. Other microalgae, such as Thalassiosira and Pavlova also show high amounts of sterols. P. lutheri contains other uncommon sterols such as brassicasterol, campesterol, stigmasterol and sitosterol apart from cholesterol (Table 2). Its is well familiar that high levels of cholestrol and LDL are of high risk for heart and coronary diseases.

Table 2: Useful bioactive compounds present in Microalgae

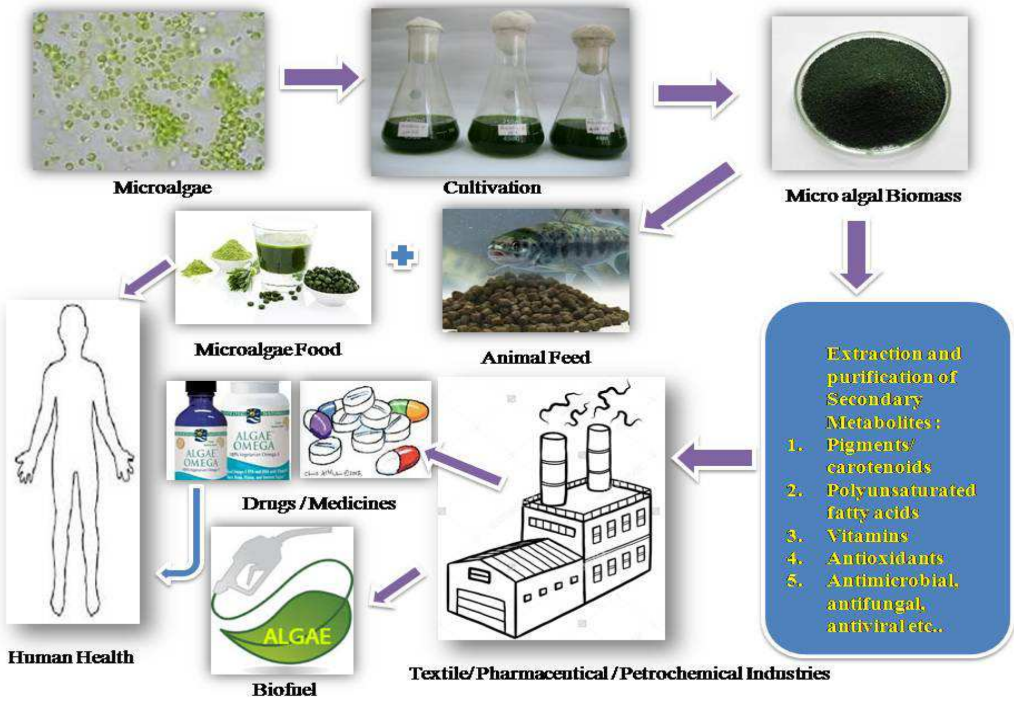
S.No	Name of the compound	Its different Types
1.	Pigments/Carotenoids	B-carotene, astaxanthin, lutein, zeaxanthin, canthaxanthin, chlorophyll, phycocyanin, phycoerythrin, fucoxanthin
2.	Polyunsaturated fatty acids (PUFAs)	DHA(C22:6), EPA(C20:5), ARA(C20:4), GAL(C18:3)
3.	Vitamins	A, B1, B6, B12, C, E, biotin, riboflavin, nicotinic acid, pantothenate, folic acid
4.	Antioxidants	Catalases, polyphenols, superoxide dismutase, tocopherols
5.	Other	Antimicobial, antifungal, antiviral agents, toxins, aminoacids, proteins, sterols, MAAs for light protection.

Proteins and enzymes

Proteins are biopolymers of amino acids, are essential for human beings, as they cannot be obtained without feeding, because of some deficiency in synthesizing them in enough amount. In addition, besides nutritional benefits some proteins, smaller peptides and amino acids have functions that contribute to a few health benefits. As microalgal species Arthrospira and Chlorella are rich in protein and amino acid they may be used as nutraceuticals or be included in functional foods to prevent tissue damage and diseases.

Vitamins
Marennine, a blue pigment responsible for greening of oysters, diatom Haslea (Navicula) ostrearia is particularly rich in vitamin E. Another microalgae named P. cruentum is rich in vitamins C, E (tocopherols) and provitamin A (β-carotene) (Table 1). In addition, *Dunaliella salina* besides producing β-carotene (provitamin A), it also produces thiamine, pyridoxine, riboflavin, nicotinic acid, biotin and tocopherol.

Figure 1 : Applications of Secondary metabolites from microalgae



Biofuel:
The natural source of renewable energy such as microalgae, can be formed from natural resources such as sunlight, water and O_2/CO_2 .The production of biodiesel and bioethanol from microalgae that have potential to replace fossil fuels being in an economic sustainable way and leading reduction of GHG emissions [32-40]. Microalgae are considered to be an outstanding candidate for biomass production (nearly 77% of dry cell mass), photosynthesis process for lipid fabrication, and production of biofuel [41-46].

CONCLUSION

The aim of this paper is to review the different bioactive compounds present in the microalgae and its applications. The extensive use of secondary metabolites as antibacterial and antifungal agents have been known for the past 60 years. Moreover, microalgae are meant to be an important raw material for amino acids, vitamins and productions of other pharmaceuticals. Other extremely successful applications of secondary metabolites are as anticancer agents, immunostimulants and cholesterol-reducing agents, among others.

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