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Review article

Cosmetic attributes of algae - A review

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ABSTRACT

Algae (macroalgae and microalgae) are aquatic photosynthetic organisms largely used due to the variety of bioactive compounds in their composition. Macroalgae have caught the attention of the food, cosmetic, pharmaceutical, and nutraceutical industries. The food industry has recently used microalgae biomass, and several others have used it as biofuel source in wastewater treatments, for example. Many algae-derived secondary metabolites are known for their skin benefits, which include protection from UV radiations and prevention of rough texture, wrinkles, and skin flaccidity. It also avoids skin aging due to the presence of antioxidant compounds. The variety of cosmetic formulations using biocompounds or algae extracts is increasing since they also provide the desired safe materials from environmental resources. Although the cosmetic effects of some of these compounds were described in recent publications, the majority of biomolecules in algae species have not yet been studied and, therefore, are not be used for cosmetic purposed. Besides that, the majority of algae effects in cosmetics are described in patents without considerable explanation about the type of biocompounds or the mechanisms responsible for each cosmetic performance. Thus, this review aimed at a better understanding of the recent uses of algae in cosmetic formulations with potential applications for new researches.

1. Introduction

Marine environment presents great biodiversity with only a few species totally described. In fact, it has been studied as a unique source of microorganisms, animals, and plants with particular characteristics.

Algae covers a range of organisms from different phylogenetic groups with approximately thirty thousand species described. In general, these can be categorized as multicellular macroalgae and unicellular microalgae (microscopic algae). However, it is necessary to consider that algae are evolutionarily heterogeneous [1]. Also, macroalgae, usually found in the coastal areas, are represented by three major classes: green algae (Chlorophyceae), brown algae (Phaeophyceae), and red algae (Rhodophyceae) [2–4]. Microalgae can be found in all ecosystems and in oceanic water areas as phytoplankton [2,3,5–7].

Algae cells transform solar energy into chemical energy through photosynthesis process. Chemical energy is stored in the form of chemical compounds with particular biological activities named “bioactive compounds”. From the perspective of Nature, the excretion of such chemicals could be related to the regulation of bacterial and algal populations [8]. Nowadays, the most important source of information for these bioactive compounds is *The Dictionary of Marine Natural Products*, which lists over 30,000 purified compounds and tends to present growing number of compounds every year [9]. However, there is no information about bioactive compounds for most of the species in marine environments.

Regarding the algae cultivation, algae species are considered the most important biomass producers for many different applications. Also, they are capable of producing bioactive compounds with potential applications in the cosmetic industry [2,3,6,10–12]. Such applications are related to thickening, water-binding, and antioxidants agents. Also, microalgae can particularly be used as nutraceuticals, additives, and natural dyes for health treatments [5,7,13–15].

As cosmetics, they are used on a daily basis by millions of people due to the ability to generate physical and psychological well-being to customers by highlighting benefits and improving their quality of life [16]. The production of cosmetics containing microalgae combined with other antioxidants and/or bioactive compounds for skin protection from sun damage is considered to be a growing field of study [2].

Algae was used as natural resource because their isolated metabolites have shown biological activities and potential to provide health benefits [2,3,17,18]. This review aims at describing the recent cosmetic uses of bioactive compounds from algae species (i.e. extracts).

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1.1. Microalgae and macroalgae

Microalgae cover a wide range of species and biochemical characteristics, with the particular physiological property of undertaking oxygenic photosynthesis [12]. They have evolved to live under limiting environmental conditions, including stress conditions such as heat, cold, anaerobiosis, high salinity, osmotic pressure, and exposure to different types of light source [19–22].

Microalgae are also major food producers, mainly for animal feeding due to its contents: fatty acids, tocopherols, sterols, proteins, carbohydrates, vitamins, minerals, antioxidants, and pigments (e.g. chlorophyll and carotenoids) [13].

Autotrophic cultivation of photosynthetic microorganism is increasing quickly, mainly in large-scale production in order to harvest enough biomass to obtain useful biomolecules. Microalgae cultivation has been developed in open ponds and photobioreactors, such as horizontal, vertical or helicoidal tubular reactors, flat-plate reactors, and membrane photobioreactors [23–26]. Tubular reactors with airlift systems are among the most popular types to enhance biomass composition for novel uses. Furthermore, microalgae could grow in heterotrophic conditions with enough nutrients, but no light availability and even in mixotrophic conditions in which nutrients are obtained both autotrophycally and heterotrophycally [11].

Only a few species of microalgae have been studied and used in some commercial applications, including: *Spirulina*, *Chlorella*, *Haematococcus*, *Dunaliella*, *Botryococcus*, *Phaeodactylum*, and *Porphyridium* [5,13,17,21,27]. For instance, colorants for cosmetic formulations such as eye shadow, face make-up, and lipstick are currently obtained from red microalgae [28].

Macroalgae, commonly named seaweeds, have been used in the production of phycocolloids, like agar and alginates [15]. Furthermore, some types of brown and red macroalgae are used in cosmetics due to the presence of vitamins, minerals, amino acids, sugars, lipids, and other biologically active compounds [15,28]. For example, *Macrocystis pyrifera* biomass was used by the food industry and also applied as a thickening agent in cosmetics by other industries [20].

1.2. Advantages of using algae

The growing necessity to obtain safe products by ecofriendly bioprocess has made algae a sustainable resource for new bio-based products [29,30]. Recently, as reported, algae have become an important source of bioactive compounds and fats [15].

They are also being used in environmental applications, such as wastewater treatment, biofuel production, CO_2 sequestration, and oxygen release to the atmosphere, contributing to the reduction of greenhouse gas effects [2,5–7,15,27,31,32].

1.3. Disadvantages of using algae

A homogeneous large-scale production of algae could pose a problem for algae applications in cosmetics. Since defining the best culture conditions during growth is essential, the variation of some parameters may influence on the final composition profile of the biomass. Such parameters include light intensity, pH control, amount of CO_2, nutrients, loss of water or even contamination [9–11].

Regarding the microalgae cultivation processes, laboratory scale photobioreactors were used to define the best cultivation conditions, i.e. medium composition and cultivation system, among others [11].

Considering macroalgae, cultures studies are necessary to establish the development from unicellular cells to multicellular thallus and even for morphological, nutritional, and physiological aspects of each species [10].

2. Algae in cosmetics

A number of secondary metabolites derived from algae are known for their skin benefits [18]. A global tendency for products considered healthy, environmentally sustainable, and ecologically obtained led to cosmetics industries to fund the research and development of new products containing compounds or extracts from natural sources.

Algae are naturally exposed to oxidative stress and develop several efficient protective systems against reactive oxygen species and free radicals, producing compounds that can act in cosmetics against the harmful effects of UV radiation, promoting similar action of organic and inorganic filters currently used in the market [27,33]. In fact, there is an increase in the production of both chlorophyll and carotenoids of *C. vulgaris*, *Nostoc*, and *Spirulina platensis* when cultivated in the presence of UV radiation [34]. Besides that, these compounds may help protect against oil oxidative process in formulations, mainly in emulsions containing large amount of oily phase, since they have antioxidant properties [27].

Fucus vesiculosus extract is used to reduce the appearance of dark circles on the skin area under the eye by stimulating the expression of heme oxygenase-l (HO-l), a molecule that eliminates the heme production on the skin by removing heme catabolites. The anti-inflammatory activity and antioxidant properties of the extract in topical formulations could improve the appearance of eye bags, and stimulate collagen production that could help to reduce fine lines and wrinkles. In addition, it could diminish or even avoid skin aging by using make-up and sunscreens [35].

Some secondary metabolites of certain microalgae can prevent blemishes, repair damaged skin, treat seborrhea, inhibit some inflammation processes and accelerate healing process, and maintain skin moisture [28].

Moreover, extracts of red microalgae can be found in skin care, sun protection, hair care, emollient, refreshing or regenerate care products, anti-aging creams, and anti-irritant in peelers [13–15,28,36–38].

Algae are mainly incorporated in cosmetic formulations as thickening, water-binding and antioxidants agents. However, more than a single contribution could be attributed to each species, as reported in Table 1 [3].

In order to better understanding the cosmetic effects of algae, these were mentioned according to the type of cosmetic product.

2.1. Sunscreen

Includes UV filters widely recommended to prevent and protect the skin from several damages, including photo-aging, sunburn, photodermatoses, and skin cancer [16,46–50]. Some algae species synthesize substances with particular chemical structures that not only absorb UV radiation, but also inhibit actions on melanin synthesis [39].

Chlorogloeopsis spp. extract provides benefits to the keratinous tissue by avoiding damages resulting from UVA and UVB radiation (production of free radicals after exposure to UV), preventing photo-aging, wrinkles formation, and skin sagging [33].

Isochrisis algae could prevent UV transmission with the same profile as a formulation containing only organic and inorganic filters with SPF 15. *Nannochloropsis* algae was also effective against UVA and UVB transmission [43]. Moreover, the use of cyanobacteria in sunscreen formulation presented better absorption in UVB-UVA region (290 to 400 nm) in relation to a commercial formulation, and also good absorption in the visible spectral region (400 to 650 nm) [44].

Furthermore, cyanobacterium *Nostoc* sp. R76DM produces UV-absorbing mycosporine-like amino acids (MAAs). MAAs as palythine, asterina, porphyra, and palythene presented in vitro dose-dependent antioxidant and in vivo reactive oxygen species (ROS) scavenging potential [51]. However, no cosmetic formulation was developed using these MAAs.