Application of Microalgae in Cosmetics

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Microalgae produce a number of secondary metabolites with anti-inflammatory, anti-blemish and antimicrobial activities. Certain microalgal extracts such as *Arthrospira platensis*, *Chlorella vulgaris*, and *Dunaliella salina* can be used for repairing skin aging, healing and preventing wrinkle formation. The microalgae or its components' activity is the basis for the creation of several commercially available cosmetics and cosmeceuticals.

natural sunscreen cosmetic Microalgae

1. Introduction

Microalgae produce a number of secondary metabolites with anti-inflammatory, anti-blemish and antimicrobial activities [1]. Certain microalgal extracts such as *Arthrospira platensis*, *Chlorella vulgaris*, and *Dunaliella salina* can be used for repairing skin aging, healing and preventing wrinkle formation [2][3][4][5]. The microalgae or its components' activity is the basis for the creation of several commercially available cosmetics and cosmeceuticals. Anti-aging creams, refreshing/regenerating care items, emollients and anti-irritants in peelers, sunscreen cream, and hair care items are a few examples of commercialized microalgae sources in the skin care industry. These cosmetics and cosmeceuticals contain bioactive microalgae components or algal extract (**Table 1** and **Figure 1**). The products could offer promising and innovative alternatives to existing cosmetics and drive the development of new functions for cosmetic products.

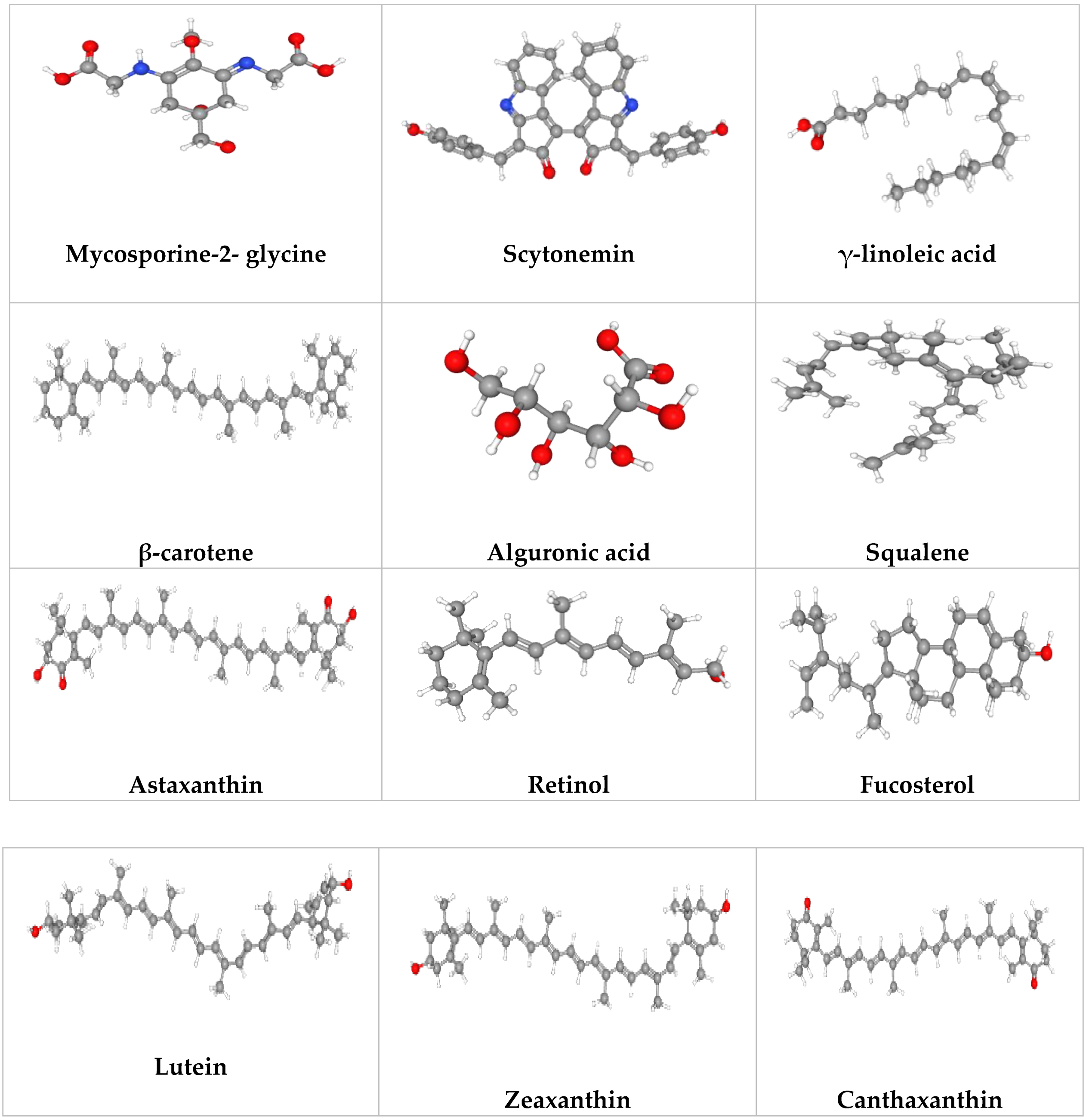

Figure 1. Potential microalgal compounds used in cosmetics such as sunscreen and anti-aging.

Cosmetic and cosmeceutical products must safeguard the natural dermal qualities and improve its appearance of health. They are typically applied when skin becomes dry due to a change in the filaggrin gene, which produces the skin's natural moisturizing component. Additionally, by protecting against both external and internal influences, they could be used to lessen the signs and symptoms of aging [6]. In addition to offering these advantages, they should have anti-bacterial and anti-fungal activities against organisms such as Mucor ramaniannus and Candida albicans to protect the equilibrium of the skin flora. Moreover, extracellular matrix stability, acne management, cell regeneration, skin whitening, inflammation control, stimulation of angiogenesis, and oxidative stress management are all areas where microalgal antimicrobial peptides play distinctive roles. Cosmetics may contain chemicals that have unintended adverse effects, such as triggering hypersensitivity reactions, anaphylactic shock, or fatal poisoning [7]. To select compounds as safe cosmetics, some crucial studies such as genetic toxicity, phototoxicity, photo genotoxicity, toxicokinetics, and carcinogenicity should be conducted. Due to the growing popularity of cosmetics, there is a greater demand for natural and sustainable resources for the manufacture of cosmetics [5]. Cosmetics made from microalgae can replace current goods and are safe for the environment; the FDA has authorized Arthrospira extract as a “safe” food ingredient.

Table 1. Potential application of microalgae as natural cosmetics.

Species	Ingredient	Activity/Uses	References
Anabaena virabilis, *Nostoc punctiforme*, *Gloeocapsa* sp.	Mycosporine-like amino acids (MAAs)	Photoprotection	[8][9]
Arthrospira platensis, Dunaliella salina, Chlorella vulgaris, and *Nannochloropsis oculata*	Sporopollenin, scytonemin, mycosporine-like amino acids (MAAs)	Photoprotection	[10]
Odontella aurita	Polyunsaturated fatty acids (PUFAs)	Prevents oxidative stress on skin	[11]
Porphyra sp., *Porphyridium* sp.	Phycoerythrin	Cosmetics (face powder, eye shadow)	[12]
Arthrospira sp.	Phycocyanin	Cosmetics (eye shadow)	[13]
Dunaliella, Nannochloropsis	Carotenoids	Wrinkle reduction, collagen formation and tissue regeneration	[14]
Arthrospira sp.	Phycobiliprotein	Improves moisture balance of the skin, skin complexion, strengthens skin’s immunity and reduces wrinkle	[15]
Dunaliella salina	β-carotene	Stimulates cell proliferation	[14]
Arthrospiraplatensis	γ-linoleic acid	Prevents early skin aging and wrinkle formation	[15]
Asterocapsa nidulans	Alguronic acid	Strengthens skin immunity	[16]
Porphyridium sp.	Sulfated polysaccharide	Strengthens skin immunity	[16]
Botryococcus braunii	Squalene	Improves skin elasticity and moisture retention, prevents age	[17]

Species	Ingredient	Activity/Uses	References
		spots and hyperpigmentation	
Haematococcus lacustris	Astaxanthin	Photoprotection	[18][19]
Nostoc commune, Anabaena variabilis, Aphanothece halophytica	Mycosporine-2- glycine	Inhibition of advanced glycation end products	[16]
Olisthodiscus luteus, Microchloropsis salina	Fucosterol	Decrease matrix metalloproteinases expression and increase collagen production	[10]
Dunaliella bardawil	β-carotene	Improves bioavailability and antioxidant properties on skin	[20]

...ary active ingredient in cosmetics, but some of these compounds also have characteristics that allow for them to be employed as excipients, such as stabilizers, dyes, or thickening agents [5][21]. Typically, personal care items, including face lotion, cream, shampoo, body soap, and colorants for cosmetics, are formulated using their extracts or bioactive compounds [6][22][23]. Their sterols can also be utilized in moisturizing lotions [24]. Moreover, their pigments, like the keto carotenoid astaxanthin and β-carotene, are utilized in skin care, anti-aging, and anti-irritant treatments [24]. In addition, β-carotene with non-modified β-ionone rings such as β-carotenes are the precursor molecules for vitamin A [23]. Fucoxanthin protects against UV-B-induced skin damage by reducing intracellular ROS, like astaxanthin, an orange-colored pigment with antioxidant and provitamin A properties. Fucoxanthin has anti-pigmentary action in UV-B-induced melanogenesis in addition to its sunscreen properties [24][25]. Fucoxanthin could be an active component of cosmeceuticals and nutraceuticals utilized in the defense of the skin from photoaging [24][26][27]. Microalgae are also a source of phenolic compounds which are valuable antioxidants and photoprotective compounds [28][29]. The green microalga *Lobosphaera incisa* accumulates triacylglycerols (TAGs) with exceptionally high levels of long-chain polyunsaturated fatty acids (LC-PUFA) and arachidonic acids (ARA) under nitrogen (N)-deprived conditions [30]. The cosmetic industry uses extracts from microalgae which are high in pigments, PUFAs, phycobiliproteins and carbohydrates which can be used to make lotions, creams and ointments. Mycosporine-like amino acids (MAAs) are small <400 Da, water-soluble, colorless UV-absorbing compounds synthesized by marine microbes as an adaptation for their high sunlight environments. They have a unique absorption spectrum between 309 and 362 nm. Structurally, MAAs are divided into two groups: (i) the mycosporines, which have a single modified amino acid residue connected to a cyclohexenone core, and (ii) MAAs, which have two such amino acid substituents [31][32]. MAAs have good antioxidant properties. MAAs produced from *Dunaliella*, *Arthrospira*, and *Chlorella* have the potential to act as sunscreens to reduce the damage induced by ultraviolet rays. Microalgae *Odontella aurita* also showed potential free radical scavenging activity to maintain youthful skin.

Adequate research is currently lacking in order to apply the findings of in vitro experiments on model organisms and the application of efficient compounds to human skin. Additionally, patients and researchers must understand that compliance is crucial when using natural cosmetics since they work more slowly than traditional cosmetics made of synthetic substances. Important research on genetic toxicity, photo genotoxicity, phototoxicity, toxicokinetics, and carcinogenicity should be carried out in order to choose substances as safe cosmetics. To specify compounds as a harmless cosmetic, certain crucial studies such genetic toxicity, photogenotoxicity, phototoxicity, toxicokinetics, and carcinogenicity should be performed [33]. Using genetic toxicity studies, such as the Ames Salmonella test, one may determine the carcinogenic potential of bio compounds produced from microalgae [34]. Moreover, the 3T3 neutral red uptake (3T3 NRU) experiment, the 3-dimensional (3D) epidermis model, and the erythrocyte photohemolysis test can be used to determine the phototoxicity of microalgal bioactive compounds. Nevertheless, as natural products have long been used to promote health and wellbeing, they may have promised nutritional and therapeutic benefits with minimal-to-no negative effects.

2. Photoprotection Prospects of Microalgal Products

Organic carbon molecules and oxygen, which are necessary for life on Earth, are produced by cyanobacteria, algae, and plants, which also turn solar energy into chemical energy. UV rays hit the Earth's surface more intensely as a result of ozone layer depletion and the rising emission of atmospheric contaminants. The ozone layer absorbs UV-C radiation, which ranges in wavelength from 100 to 280 nm. The ozone layer blocks most of the ultraviolet-B (UV-B) radiation (280–315 nm) that reaches the Earth's surface, but some do get through. As the ozone layer thins, UV-B radiation intensity rises. However, the ozone layer has little effect on ultraviolet-A (UV-A) light, which ranges in wavelength from 315 to 400 nm (320 to 400 nm). The primary kind of solar radiation that enters our atmosphere is UV-B, which harms living things exposed to the sun by causing DNA strand breaks, membrane rupture, enzyme deactivation, the production of cytotoxic DNA lesions, and other extremely hazardous effects. Because native DNA molecules cannot absorb UV-A radiation, ROS are created, which cause indirect DNA damage [35]. As a result of these consequences, UV-A and UV-B have mutagenic and carcinogenic effects on humans, speed up the skin's aging process, and cause photodermatitis. In order to defend themselves from UV radiation, microalgae have developed a number of defenses, including (i) the expression of DNA-repair enzymes; (ii) the creation of antioxidant enzymes; (iii) the avoidance of the UV; and (iv) the production and accumulation of UV filter metabolites [36]. These mechanisms, along with the manufacture of UV filter metabolites, commonly known as "microbial sunscreens", make microalgae potential candidates for the cosmetic sector to be employed in sunscreens produced from natural sources [35][37].

To defend themselves from sun radiation, microalgae produce a variety of UV filter substances, including sporopollenin, scytonemin, mycosporine-like amino acids, β-carotene, and other substances such as biopterin glucoside, lycopene, and ectoine for UV protection and photoaging [10]. These bioactive substances shield the body from skin cancer, sunburn, and other diseases by inhibiting the manufacture of melanin, among other things.

The skin is shielded from UV damage by lutein, which is generated by Chlorella protothecoides, Scenedesmus almeriensis, Muriellopsis sp., Neospongiococcus gelatinosum, Chlorococcum citriforme, Chlorella zofingiensis, D. salina, and Galdieria sulphuraria [5][21][38]. The chemicals in microalgal extracts or extracts from microalgae help shield the skin from UV damage [5]. The most significant and extensively researched compounds that are utilized in sunscreens made by microalgae are scytonemin and mycosporine-like amino acids. Cyanobacteria produce scytonemin—a lipophilic, extracellular yellow-brown pigment—in their sheath when exposed to intense sun radiation in order to shield themselves from UV-A radiation with an absorption of up to 90% [36][38][39]. Scytonemin has a maximal absorption range of 252–386 nm [36][40][41]. Coelastrin A and Coelastrin B, two novel MAAs from Coelastrella rubescens, exhibit photoprotective properties [42]. Klebsormidin A and klebsormidin B, the newly identified MAAs from Klebsormidium, showed that their biosynthesis and intracellular enrichment is strongly induced by UVR exposure, supporting the function of these compounds as natural UV-sunscreens [43].

Scytonemin is produced when the gene responsible for its production is activated by UV-A, and it then builds up in the body. Scytonemin and derivatives of scytonemin can be produced by a number of cyanobacterial species such as *Anabaena*, *Calothrix*, *Chlorogloeopsis*, *Diplocolon*, *Gloeocapsa*, *Hapalosiphon*, *Lyngbya*, *Nostoc*, *Phormidium*, *Pleurocapsa*, *Rivularia*, *Schizothrix*, *Scytonema*, *and Tolypothrix* [35].

The hydrophilic and colorless mycosporine-like amino acids (MAAs) are produced by marine organisms such as cyanobacteria [44][45], microalgae, macroalgae, fungi, etc., that act as an antioxidant by preventing ROS-induced DNA damage as well as a photoprotectant by shielding cells from UV-B and UV-A radiation by absorbing radiation and dissipating excess heat energy into the cell and surroundings [46][47][48]. Only a small percentage of the physical and chemical filters on the market, referred to as “broad-spectrum sunscreen”, can effectively block both UV-A and UV-B rays [49]. Therefore, it is crucial to include MAAs as a UV filter agent in sunscreens since they have a high capacity to absorb UV between 309 and 362 nm, making them a broad-spectrum sunscreen [37]. They can be a very stable cosmetic product because they are also very photostable and very resistant to heat, pH fluctuations, and different solvents [50]. The first sunscreen product, named Helioguard 365, was created by the Swiss company Mibelle AG Biotechnology using a natural UV screening substance called an MAA containing a certain proportion of Porphyra-334 and shinorine obtained from red algae *Porphyra umbilicalis* [51][52].

3. Microalgal Compounds as Anti-Aging Therapies

The formation of AGE (advanced glycation end products), the impact of ROS, and matrix metalloproteinases (MMPs) are the most important processes among theories about the aging process. Pharmaceutical companies have recently become interested in substances that are preventing AGE. Recently described as an inhibitor of AGE formation, mycosporine-2-glycine (M2G), a very uncommon mycosporine-like amino acid, has been proposed as a key component in anti-aging therapies [53]. *Nostoc commune*, *Anabaena variabilis*, and *Aphanothece halophytica* have all been found to be capable of producing mycosporine-2-glycine. The key strategy to delay the aging of the skin is moisturization. It can support skin elasticity and beauty maintenance and increase environmental harm prevention. Hydroxy acid (HA) benefits the skin and has been utilized in cosmetic goods to moisturize skin. Plants are capable of producing hydroxy acids, but because plant output is restricted, interest in algal polysaccharides is growing. According to studies, *Pediastrum duplex* extract has a significant number of polysaccharides and can be used to preserve and moisturize skin [5]. Salicylic acid, α-HA, and β-HA are different types of HA. Due to the hydroxyl group connected to the carbon atom adjacent to the carboxyl group, α-HA is also known as 2-hydroxy acid. Lactic and glycolic acids are cosmetics’ two most widely used 2-hydroxy acids. As a result of the hydroxyl group linked to the carbon atom that comes in second place when counting, starting from the carboxyl group, β-HA is also known as a 3-hydroxy acid. Citric acid is the most well-known 3-hydroxy acid utilized in the cosmetic formulation [54]. *A. variabilis*, *Anacystis nidulans*, *Chlorella pyrenoidosa*, *Chlamydomonas reinhardtii*, *Cyanidium* *caldarium*, *Phormidium foveolarum*, and *Oscillatoria* species have also been shown to create 2-hydroxy acids and 3-hydroxy acids, and their extracts can act as antioxidants [55][56].

4. Microalgal Product's Potential as Skin Whitening Agents

The pigment melanin is what gives hair, skin, and eyes their pigmentation, and it is created to protect the skin from UV damage. Nevertheless, melanin overproduction gives the skin a distinct color [5][57]. Tyrosinase is a crucial enzyme that starts the manufacture of melanin, and tyrosinase inhibitors can stop pigmentation in the skin [58]. Tyrosinase inhibitors contain phenolic structures or metal chelating groups, which result in two mechanisms: inhibiting interactions between the substrate and the enzyme and chelating copper within the active site of the enzyme. Finding novel, naturally derived alternatives to these synthetic tyrosinase inhibitors is important due to their high toxicity, low stability, insufficient action, and poor skin penetration, and microalgae can serve as a promising possibility [59]. *S. plantensis* extracts can be employed as tyrosinase inhibitors [59]. According to Oh et al. (2015), *Pavlova lutheri* inhibits melanogenesis [60]. Tyrosinase inhibitory activity was also demonstrated by Oscillapeptin G from *Oscillatoria agardhii*, asthaxanthin from *Haematococcus pluvialis*, and zeaxanthin from *N. oculata* [61]. In addition to inhibiting the tyrosinase enzyme, vitamins C and E can inhibit the skin's synthesis of melanosomes. A well-known NADH (Nicotinamide Adenine Dinucleotide Hydrate)-based process that protects mammalian skin from UV radiation damage is the self-acting, synergistic combination of vitamins E and C. Pediastrum cruentum's high concentration of vitamins E and C make it a potential candidate as a cosmetic to prevent melanoma [62].

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