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Applications of Algae in Cosmetics: An Overview

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ABSTRACT: Algae are oxygenic photosynthetic organisms that are mainly found in aquatic environments and wetlands. There is an increasing trend in the usageof photosynthetic microorganisms including macro- and micro-algae in the field of Cosmeceuticals by incorporating the bulk products extracted from its biomass into cosmetic formulations.There are many scientific corroboration that proves the competence of algae but of course, it depends on specific type of extract, how it is processed and its application. Due to the growing economic aspect of the cosmetic industry, the need for harmless and efficient natural raw ingredients has become an utmost necessity.According to certain research reports, algal products used in cosmeceuticals have been known to be suitable alternatives with constructive effect even after prolonged usage. Diverse algal species are now being used widely for the treatment of various skin related problems by acting as a moisturizer or texture enhancing, sunscreens, anti-wrinkling, etc. This review basically focuses on the commercial value of various algal products extracted from both macro- and micro-algal species for its use as a substitute in the biotechnology and cosmetic industry.

KEYWORDS: Cosmeceuticals, anti-tanning, anti-ageing, skin sensitizers, soothing agents, moisturizers, antioxidants, texture enhancer, thickening agent.

I. INTRODUCTION

The term Cosmeceuticals is a consolidation of cosmetics and pharmaceuticals, encompassing the biologically active compounds retaining therapeutic value. These are assortments of various chemical compounds, some of which are acquired from natural sources like plants, animals, algae, minerals, while others are synthetic like sodium lauryl sulphate, PVP, ethyl paraben [1]. Algal products have been used in the cosmetic industry as antioxidants, sunscreens, thickening agents, skin sensitizers, moisturizing agents to enhance the competence of skin against abrasions, tanning, etc. [2]. Algae are primitive unicellular or multicellular eukaryotes, which are photosynthetic, i.e., they are primary producers harnessing energy from sunlight and converting it into chemical energy for the biosynthesis of organic compounds such as sugars. Algal species contain a green coloured pigment recognized as chlorophyll, which is an imperative component in the process of photosynthesis. These pigments assist in absorption of energy from the light source and transferring it to the reaction centre of photosystem I and II. These pigments can be differentiated into two types, chlorophyll a and chlorophyll b. Thus, carbon dioxide, water, and sunlight are utilized, to convert oxygen into sugars like glucose/starch and biomass [3]. Algal species can withstand extreme environment conditions of pH, temperature, osmotic pressure, salinity, exposure to ultraviolet rays, anaerobiosis and are able to thrive efficiently under these diverse conditions. They are able to defend its cellular components by the counter production of primary metabolites such as oleic acids, vitamin E, vitamin B_{12}, lutein, and zeaxanthin [4]. Secondary metabolites are also generated under harsh conditions in which they might be present. These metabolites possess antibiotic and antimicrobial effect against pathogenic fungi and viruses [5]. Algae are further divided into two major categories, micro-algae and macro-algae.

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A. Micro-algae

Microalgae also known as blue green algae or cyanobacteria are prokaryotic, microscopic unicellular algae having an approximate diameter of 1-50 µm. They are phototrophic, but some can also grow heterotrophically. They carryout oxygenic photosynthesis that is quite similar to that found in terrestrial plants, utilizing carbon and light (radiant) energy for their metabolism [6]. They exist individually, in chains or cluster. Micro algae contain phosphorous, calcium, iron, vitamin A, B, C, E, folic acid, biotin, beta-carotene, pantothenic acid and vitamin B_{12} [7]. There are some micro-algal species that can adapt to changes when phosphorus is exhausted in the environment; some species of microalgae possess the ability to substitute non phosphorus membrane lipids in place of phospholipids [8].

B. Macro-algae

Macro-algae are eukaryotic, macroscopic multicellular algae, widely known as seaweeds. The habitat of macro-algal species is marine water or sea water with the optimal availability of light [9]. They are benthic plants, therefore, their viability depends on how closely attached they are with the seabed or a solid underlying layer of rock. Macro-algal species have simple structure consisting of thallus, lamina, kelp, holdfast and frond sorus, thus morphologically differentiating itfrom the typical terrestrial plant, consisting of complex tissue and organ organization [10].
Macro-algae can be divided into three major groups based on their pigmentation [9]:

- *Chlorophyceae* (green algae)
- *Phaeophyceae* (brown algae)
- *Rhodophyceae* (red algae)

II. RELATED WORK

According to "Malthusian Theory of Population", Malthus predicted that exponential population burst would gradually surpass the availability of food, and thus in 1890s experts suggested alternate food sources like algae, yeast, and fungi. Therefore, to find an unconventional food source, researchers in 1948, were able to cultivate *Chlorella* under optimal conditions in shallow ponds. It was observed that *Chlorella pyrenoidosa* was able to convert radiant energy in the presence of CO_2 into its biomass, which contained 50% protein [15]. Even today *Chlorella spp.* is being used as a dietary supplement. Milledge, et al. (2014) in their paper "Macroalgae-derived biofuel: A review of methods of energy extraction from seaweed biomass" stated that due to increased exploitation of algal products, the industry has gained a multibillion-dollar status. Algal metabolites especially three major phycocolloids are being used proficiently in food and cosmetic industry as value added ingredient [9]. Micro-algae have been used for various industrial applications, mainly due to its ability to produce biologically active compounds. For obtaining such compounds, attention should be given to the cultivation conditions of micro-algal species such as pH of the medium, incubation temperature, light intensity, the type of bioreactor used and medium composition. These cultivation conditions influence the rate of metabolism of the micro-algae used [4]. The different cultivation systems used in the Netherlands are horizontal tube reactors, three-dimensional tube reactors, flat plate reactors and raceways [6]. For the extraction and purification of phycoerythrin pigment from Mediterranean red algae (*Corallina elongata*), Rossano, et al. (2003) in their paper "Extracting and purifying R-phycoerythrin from Mediterranean red algae *Corallina elongata* Ellis & Solander" stated a one-step procedure, in which the purification was centred on the use of hydroxyapatite chromatography technique [19].

III. PIGMENTS PRODUCED BY ALGAE

A. RED ALGAE

The red algae produce a photosynthetic red protein pigment called phycoerythrin along with chlorophyll. This pigment imparts color to red algae due to its light-harvesting property in which the red light is reflected, while blue light is absorbed [19]. The protein is covalently bonded to phycobilins containing chromatophores. The presence of the stated pigment enables these algal species to carry out the process of photosynthesis [20]. Some species of red algae used in cosmetics are Irish moss, *Gracillaria* spp., *Porphyra* spp., etc.

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B. GREEN ALGAE

It produces photosynthetic pigment chlorophyll, which is able to trap light energy. This pigment is similar to the red pigment called Haemoglobin present in human red blood cells. It provides oxygen to the exposed surface of the algal species and prevents it from drying by moisturizing it. It also possesses anti-inflammatory effect [21]. Some species of Green algae used in cosmetics are *Chlorella vulgaris*, *Ulva lactuca*, etc. β-carotene obtained from *Dunaliella salina* is used as colorants and food supplements as a nutraceuticals as it is a precursor of vitamin A [22].

C. BROWN ALGAE

Fucoxanthin is a supplementary pigment found in the chloroplast of brown algae. It has tyrosinase inhibitory effects which helps to reduce or control skin pigmentation, possesses anti-inflammatory effect and also, assists in preventing natural aging of the skin by supporting the formation of collagen (a structural protein which tends to disperse with age). Furthermore, the pigment moisturizes the skin and keeps the skin cells working efficiently [23]. Some species of brown algae used in cosmetics are *Isochrysis spp.*, *Postelsiapa maeformis*, *Laminaria digilata*, etc.

IV. BIOTECHNOLOGICAL APPLICATIONS OF MACRO- AND MICRO-ALGAE

Algal species are extensively sought after to aid in various biotechnological applications (Table 1). The use of algae has been possible due to its features such as high growth rate, controlled pigmentation, simple harvesting methods,etc. that makes it a suitable system for biotechnology. These algal species are used as biofertilizers to stimulate plant growth by increasing the nutrient content. Organisms like *Spirulina spp.*, *Gigartina spp.* and *Chlorella spp.* are used as dietary supplements, providing high protein content that boosts immunity. Other unique species of algae are used specifically for wastewater treatment and as stabilizing agents in food industry. *Heterosigma spp*. are being extensively and selectively used as biofuel producers, these species are capable of producing biomass, which can be burned to produce heat and electricity and reduce the concentration of harmful pollutants by converting them to organic residuals.

Table:1. Biotechnological applications of algae

Application	Organism	Type of algae	Significance
Fertilizers	*Laurencia obtuse*	*Rhodophyceae*	Increase in plant length, potassium content, leaves number, plant fresh weight, and nitrogen content [11]
	Nostoc, Anabaena	*Cyanophyceae*	Stimulates plant growth, fix atmospheric nitrogen[12]
Dietary Supplements	*Spirulina spp.*	*Cyanophyceae*	Contains 60% protein, source of vitamin B, source of iron and manganese [13]
	Gigartina spp.	*Rhodophyceae*	Boosts immune system and fights viruses [14]
	Chlorella spp.	*Chlorophyceae*	High protein content, controls weight, prevention from cancer, boost immunity [15]
Biofuels producers	*Heterosigma akashiwo*	*Raphidophyceae*	Neutralizes nitric oxide gas. Produces huge amounts of carbohydrates that can converted into bioethanol [16]

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	Chlamydomonas reinhardtii	*Chlorophyceae*	Produce biomass, which can be burned to produce heat and electricity [17]
Stabilizing agent in food products	*Mastocarpus stellatus*	*Rhodophyceae*	Excellent stabiliser in milk products, reacts with the milk protein casein, Also used for toothpaste, ice-creams and lotions [17]
Wastewater treatment	*Scenedesmus* spp.	*Chlorophyceae*	Settling and bio flocculation, simultaneous algae biofuel production [18]

V. APPLICATIONS OF ALGAE IN COSMETICS

A. Skin whitening and anti-wrinkling

When direct exposure between skin and UV rays is established for a long period of time, the radiation is absorbed by melanin, a complex polymer pigment which imparts colour to human skin and also acts as a protective barrier for human skin cells [24].Thereby constant exposure to sunlight, increases melanin in the skin resulting in tanning. Radiation from sunlight helps synthesize tyrosinase which helps to catalyse reactions for the formation of melanosomes, which then mature into melanin and is further differentiated into keratinocytes to augment the dilapidation of skin. Thus, the hydroxylation of L-tyrosine to 3, 4-dihydroxy-L-phenylalanine and L-DOPA takes place where the latter undergoes oxidation resulting in the formation of dopaquinone. Melanin is then converted from the dopaquinone formed. The large amount of melanin formed causes skin pigmentation and needs to be constrained. Thus, tyranose inhibitors are used to catalyse rate-limiting step in the process of pigmentation [25]. Pigments from algae such as fucoxanthin from brown algae *Laminaria japonica*, *Alaria, chorda*, and *Macrocystis* help to reduce the activity of tyrosinase and melanogenesis [23].

B. Algae against skin aging

Skin aging is a complex biological activity which refers to the loss of elasticity of skin, appearance of fine lines, ridges, creases and discoloration of the skin with growing age [26]. Our skin is subjected to extreme severities of harsh environmental factors and thus, skin problems like dryness, thinning, skin laxity, fragility, enlarged pores, and sagging of skin leads to premature wrinkles as the elastin fibres slowly undergo deterioration [27]. The natural process of wrinkling of skin is amplified if there is a continuous exposure of heavy metals, nutrient deficiency, and lack of moisture on the epidermis. The most common cause of skin aging is reactive oxygen species (ROS), such as peroxides, superoxide, hydroxyl radical, and singlet oxygen. The protein kinase is stimulated by ROS which phosphorylates transcription factor, activator protein 1,whose function is to usually control gene expression in response to cytokines. This transcription factor triggers an increased regulation of matrix metalloproteinase leading to the dilapidation of collagen from the skin [24]. Recent scientific studies have led to promising conclusions about how algal products, such as vitamin E which is a fat soluble antioxidant and pigments such as carotene can rejuvenate and help the skin to be immune towards skin aging, and also decrease the risk of skin cancer among the users [28]. The antioxidant properties of β-carotene found in green and red algae help against skin aging [29]. Algal species such as *Turbinaria ornate*, *Ahnfeltiopsis*, *Colpomenia*, *Gracilaria, Halymenia, Hydroclathrus*, *Laurencia, Padina, Polysiphonia* are used as anti-

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aging agents [30]. Mycosporine like amino acid (MAAs) protects against UV-A which can cause skin damage and premature skin aging. MAAs are found in *Porphyra umbilicalis* [31].

C. Algae as moisturizing agent

A moisturizer is made up of a complex mixture of chemical compounds which make the epidermis of skin softer. If the skin is not properly moisturized, it is prone to acne aggravation and can even cause eczema. Thereby, moisturizers help in retaining the moisture of the skin preventing drying, bruising and wrinkling. Water along with certain acids such as hyaluronic helps in moisturizing the human skin [32]. Polysaccharides such as alginate, agar, carrageenan, and fucoidans (Table 4) from certain algal species help to regulate the distribution of water in the skin. These polysaccharides are non-toxic, economical, abundant in the algal biomass which can be used as an alternative for lightweight oils, such as acetyl alcohol, or silicone-derived ingredients [5]. Studies have shown how polysaccharides from certain algal species like *S. japonica*, *Chondrus crispus*, and *Codium tomentosum* helps in the absorption of water or moisture, providing soothing effect, that aids in proper water circulation. This keeps the skin moisturized in extremely hot and dry environments [33].

D. Algae as thickening agent and skin sensitizer

Thickening agents are used in lotions or other cosmetic products if the water content is high in the formulation to prevent inconsistency. Thickening agents used in cosmetics include polyethylene glycol and vegetable gum [34]. Agar works as a binder which is found in the cell wall of red algal species *Gracillaria* and *Gellidium*. Carrageenan obtained by *Chondrus crispus*, is another kind of thickening and stabilizing agent [35]. Some algal species can also be inculcated in cosmetics as skin sensitizers as they contain pigments such as phycocyanin, proteins, vitamin A, sugars, carrageenan which are useful and constructive for skin [36].

E. Algae as antioxidants

Antioxidants are chemicals that transfer electrons to an oxidizing agent providing glowing skin by preventing skin damage. An antioxidant helps in skin tightening, reduction of wrinkles and reduces inflammation. Retinoic acid is a type of vitamin A which reduces dark spots, dark circles and wrinkles, it also boosts skin elasticity [30]. It has been found that cyanobacteria blooms produces retinoic acid [37]. Carotenoids are fat-soluble accessory pigments which help algae to harvest light in conjunction with chlorophyll to carry on the process of photosynthesis [38]. Vitamin C and Vitamin A serve as natural antioxidants. Algae like *Spirulina maxima* and *Chlorella vulgaris* contains vitamins which also aids in skin toning, healing of dark circles, purifying skin, encouraging hair growth by treating dandruff [39].

VI. SOME OF THE ALGAL SPECIES USED IN COSMETICS

Algal species found in seabeds and pools, are collected and through different methods the biomolecules / pigments are extracted and incorporated in certain cosmetic products with a wide range of functions. The metabolites serve as agents for the treatment of skin, like anti-wrinkle or moisturizing agents. Polysaccharides such as alginates, carrageenan, and agar derived from *Phaeophyceae* and *Rhodophyceae* act as gelling agents in various shampoos, lotions, etc. Apart from this,the ingredients of macroalgae possess stabilizing, preserving and organoleptic (substances that can be perceived through senses involving smell, touch and sight) properties (Table 2).

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Table:2. Macro algal species used in cosmetics

Algal species	Type	Pigment	Fatty acids/Metabolites	Applications/ Products
Irish moss	Red algae	Phycoerythrin	Omega-3 fatty acids, Omega-6 fatty acids	Emollient, moisturizing, sheaths damaged or dry hair, nutritive, Skin soothing, anti-inflammatory [41]
Sea Lettuce *(Ulvalactuca)*	Green algae	Chlorophyll-a, Chlorophyll-b, β-Carotene	Oleic acid, Linoleic, and Linolenic acid	Antioxidant, anti-inflanrnmtoiy, skin elasticity, collagen synthesis, anti-wrinkle,emollient, moisturizing [42]
Sea Palm *(Postelsiapal maeformis)*	Brown algae	Chlorophyll-c, Fucoxanthin		Skin softening, anti-wrinkle, nourishing, moisturizing, anti-inflammatory [43]
Fucus vesiculosus	Brown algae	Chlorophyll-c, Fucoxanthin		Tightening effect and stimulates metabolism [44]
Porphyra umbilicalis	Red algae	Phycoerythrin	a-Linolenic acid,	Skin-conditioning agent [45]
Ascophyllum nodosum	Brown algae	Chlorophyll-c	Fucoxanthin, Alginates	Anti-aging agent, anti-wrinkle agent, smoothing agent [46]

Unicellular microalgal species like *Spirulina, Chlorella*, and others find an active role in the cosmetic industry as the pigments/metabolites produced by these organisms, enriches the beauty products. The amino acids and proteins from certain species of algae possess natural moisturizing ability which is exploited to the utmost for the purpose of keeping the skin hydrated and prevents drying of the skin cells [31]. Other algal metabolites such as lipids (carotenoids, sterols), phycobiliproteins (phycocyanin), terpenoids and pigments, contains anti-inflammatory and anti-oxidant activities, alongwith acting as stabilizing agents in emollients. More effective bioactive compounds can be developed by gaining better understanding of algal cultivation method and its genetics [40] (Table 3).

Table: 3. Micro algae species used in cosmetics

Algal species	Type	Pigment	Fatty acids/ Metabolites	Applications/ Products
Spirulina	Blue green algae / cyanobacteria	Phycocyanin	Gamma-Linolenic acid, Phycocyanobilin, Phycoerythrobilin	Anti aging, anti-wrinkle, collagen synthesis, anti-inflammatory, nourishing, antioxidant [47]
Isochrysis	Brown algae	Cantaxanthin, Fucoxanthin	Mistiric Acid, Oleic Acid	Antioxidant, suncare, soothing agent, anti-irritant [48]
Dunaliella salina	Green algae	Chlorophyll-a, Chlorophyll-b, β-Carotene	Palmitic acid, Linolenic acid, β-Cryptoxanthin	Antioxidants, smoothing agent, Anti-inflammatory [49]

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Chlorella vulgaris	Green algae	Chlorophyll-a, Chlorophyll-b, β-Carotene	Palmitic acid Palmitoleic acid, Polysaccharides,	Anti-aging, de-pigmentation, moisturizing and thickening agent [50]
Tetraselmissuecica	Green algae	Chlorophyll-a, Chlorophyll-b, β-Carotene	Palmitic acid, Stearic acid andVitamin E (α-Tocopherol)	Anti-oxidant, protective activity [51]
Botryococcus braunii	Green algae	Chlorophyll-a, Chlorophyll-b, β-Carotene	Palmitic acid, Stearic acid	Anti-oxidant [52]

VII. COSMETIC PRODUCTS USING ALGAL METABOLITES

In the current scenario, a large number of small and large scale business entities have inclined profusely towards using algal metabolites in their cosmetic products (Table 4). For example, the algal products of these companies range from sea-wed powder and fertilizers from Red algae, algal proteins for hair therapy, astaxanthin in cosmetics, food and beverages, etc. Swiss snow algae mixed with sea almond oil is used in anti-ageing cream. These companies often guarantee the products to be completely organic and health centric. Organisms such as *Spirulina*, *Dunaliella* spp, *Chlamydomonas* spp, etc. add value to these products by producing metabolites such as asthaxanthin, certain proteins, MAA, etc. that facilitates in the nourishment of skin and hair. Red algal species possesses cleansing properties which refine the skin assisting in the overall health of skin cells.

Table: 4. Companies using algal products

Company	**Product name**	**Algae**	**Applications / Product**	**Reference**
Aquarev industries	-----	Red algae	Carrageenan and *Kappaphycus alvarezii* cultivation, sargassum seaweed powder, seaweed, liquid fertilizer	www.aquarev.in/
Algatech	-----	Green algae	Supplies astaxanthin, obtained from *Haematococcus pluvialis*, which is used as dietary supplements, in cosmetics, food and beverages.	https://www.algatech.com/
Nykaa	Iraya algae body serum	Green algae and *Spirulina*	It moisturizes and conditions the skin, making it soft.	http://www.nykaa.com/
L'Oreal Paris	Pure face mask	Red algae	Made from clay and red algae. It exfoliates, refines the skin and has cleansing properties of Red algae.	https://www.lorealparis.co.in/
La Prairie	Cellular Swiss ice crystal dry oil	Snow algae (*Chlamydomonas nivalis)*	Anti-aging cream which contains Swiss snow algae mixed with sea almond oil.	http://www.laprairieswitzerland.com/

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Aubrey Organics	Blue Green Algae Hair Rescue Conditioning Mask	Blue-green algae	Algal protein present helps in strengthening of hair and prevents breakage and split ends.	http://aubreyorganics.com
Algenist	REVEAL Color Correcting Eye Serum Brightener	Green algae (*Dunaliella salina, (Haematococcus pluvialis*)	A concealer that reduces uneven skin around the eye and covers dark circles.	https://algenist.borderfree.com
Dove	Dove Regenerative Repair Shampoo	Red algae	It provides nourishment to damaged hair and repairs it, restoring hair strength.	https://www.purplle.com
Jenelt	Ultra UV Defence Brightening Cream with SPF 30 Sunscreen	Red algae (*Porphyra umbicalis*)	A sunscreen with antioxidants which prevents the skin from UV rays and premature skin ageing.	http://www.jenelt.com/
Osea	Osea eyes and lips	Red algae (*Chondrus crispus*)	It hydrates the delicate skin around the eyes and lips.	https://oseamalibu.com/

VIII. CONCLUSION

Algal species are now actively being utilized proficiently in the diverse cosmetic products as a reliable organic ingredient and also to add value to these products. The main constituent of the algal product are the pigments produced by these photosynthetic organisms. The algal metabolites such as polysaccharides, MAAs, proteins, etc. have diverse functions and applications. They enhance the health of the skin by acting as anti-aging, antioxidant, anti-inflammatory, anti-wrinkling and collagen boosting agent**.** Algal species are also used in various other biotechnological industries such as biofuels, biofertilizers, dietary supplements, etc. This review mainly focuses on the growing applications of algae in the cosmetic industry.

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