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ALAGE: AN EXTENSIVE ANALYSIS OF ITS ROLE IN THE COSMETIC LANDSCAPE

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Abstract
Skin is considered as the mirror of the body's health, and thus, prevention or treatment of any skin problems is an important idea Algae are among the richest aquatic resources that are regarded as healthy and barely affect cytotoxicity in people. They are regarded as a useful source of bioactive substances, such as vitamins, polyphenolic compounds, carotenoids, chitin, and others with potent skin-beneficial properties.The demand for safe and effective natural raw materials has increased due to the beauty industry's expanding economic importance.Algal compounds used in cosmeceuticals have reportedly been found to be viable alternatives with positive effects even after continuous use, according to several research findings. Nowadays, a wide range of algae species are utilized extensively to treat a variety of skin-related issues by serving as a moisturizer or texture enhancer, sunscreens, anti-wrinkling, etc. The key algal bioactive components and their impacts on skin are outlined in this review. The study also mentions some studies on the application of algae-derived ingredients in skin care. An affordable, secure, and healthy replacement for synthetic products is provided by algae use in the cosmeceuticals sector.

Keywords: Algae, bioactivity, cosmetics, skin care, anti-tanning, anti-ageing, , skin sensitizers, moisturizers, antioxidants, texture enhancer, thickening agent.

1) INTRODUCTION

The word "cosmeceuticals," which encompasses the therapeutic value of physiologically active substances, is a merger of cosmetics and pharmaceuticals [1,2]. There are many distinct chemical compounds; some are produced synthetically, including sodium lauryl sulfate, polyvinylpyrrolidone, and ethylparaben [3,4], while others are derived from natural sources, like plants, animals, minerals, and algae. Algae are unicellular or multicellular primitive eukaryotes that may photosynthesize [5]. Algae biosynthesize important chemical molecules in their cells while using sunlight as an energy source [6]. Algae can endure in any kind of environment [4], which makes their cultivation very easy. Algae species are regarded as the most significant biomass producers for a variety of purposes when it comes to algae farming.

Additionally, they have the ability to produce bioactive substances that may find use in the cosmetic sector [7,8,9,10,11]. Applications for these substances include those that include thickening, water binding, and antioxidants. Microalgae can also be employed as natural colors, additives, and nutraceuticals for medical therapies [12,13,14,15]. Algal compounds have been employed in the cosmetics industry as antioxidants, sunscreens, thickening agents, skin sensitizers, and moisturizing agents to increase skin's resistance to abrasions, tanning, etc. [16]. Therefore, the scientific community

is attempting to separate and categorize potential cosmeceutical chemicals from microalgae [17]. The current development in using bioactive chemicals derived from algae as potential cosmeceuticals is discussed in the present review, which summarizes a few studies on the subject.

2) Natural cosmeceuticals from algae

Cosmetics are any items designed to be used on a person's skin, hair, nails, lips, or mouth [18,19]. The creation of cosmetic goods has changed in recent years to incorporate more natural, ecological, and affordable production techniques as a result of growing customer interest in "greener" cosmetics [20,21]. The natural chemicals extracted from renewable raw materials also offer a more environmentally responsible option when compared to typical petrochemical ingredients, which are non-renewable and linked to greenhouse gas emissions [22,23]. Algae have emerged as one of the most vital natural cosmetic components on the market as the use of natural cosmetics has increased due to increased consumer awareness [24]. There are numerous kinds of cosmetics based on algae available on the market (Fig. 1). Nowadays, a lot of cosmetic manufacturing companies produce products that incorporate algae due to its natural origin [78]. Various bioactive substances and algae have different impacts on the condition of the skin. Algae are utilized in a variety of cosmetic products, including the bulk of high-tech cosmetics and cosmeceuticals intended to treat conditions like eczema, psoriasis, and acne [79]. They are also used in simple toiletries like body lotions, face masks, and shampoos.

(Fig: 1)

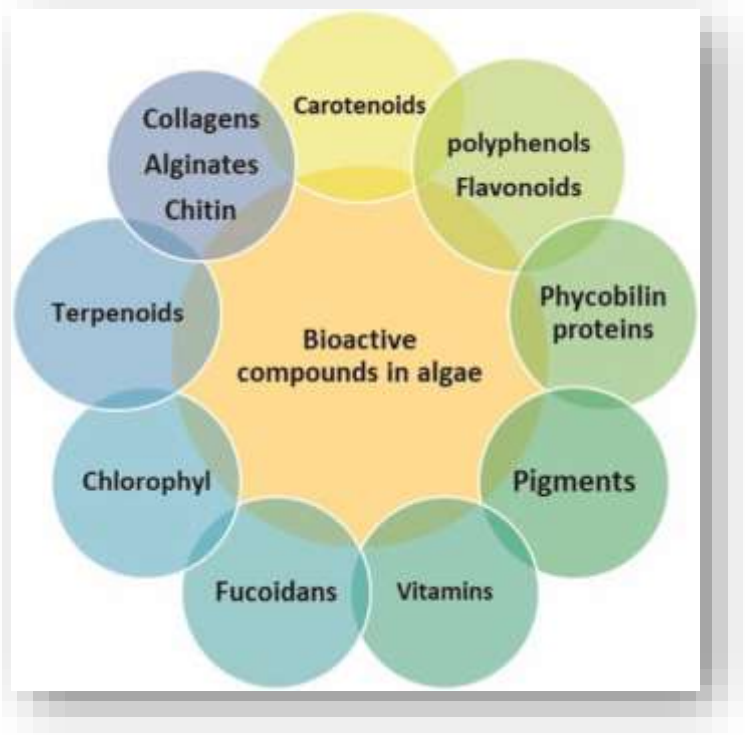
3) Main classes of algal compounds used in cosmetics

- Micro-algae
- Macro-algae

➢ **Micro-algae:-** Microalgae, sometimes referred to as blue green algae or cyanobacteria, are prokaryotic, tiny, unicellular algae with an approximate diameter of 1 to 50 m. They are phototrophic, although some of them can also grow heterotrophically. They use carbon and light (radiant) energy for their metabolism, carrying out oxygenic photosynthesis that is fairly similar to that found in

terrestrial plants [25]. They can be found singly, in groups, or in chains. Microalgae are rich in phosphorus, calcium, iron, vitamin A, B, C, and E, as well as folic acid, biotin, beta-carotene, pantothenic acid, and vitamin B12 [26]. In addition, algae produce bioactive compounds such as antioxidants, pigments, chlorophylls, and phycobilins [27](Fig.2).

➢



[Fig 2]

1) **Macro-algae:-** Seaweeds known as macroalgae have been utilized to make phycocolloids like agar and alginates [15]. Additionally, because some varieties of brown and red macroalgae include vitamins, minerals, amino acids, carbohydrates, lipids, and other physiologically active substances, they are employed in cosmetics [15,28]. For example, *Macrocystis pyrifera* biomass was employed as a thickening ingredient in cosmetics by other industries and also used by the food business [29].Macro-algae can be divided into three major group based on their pigmentation[30].

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

4) PIGMENTS PRODUCED BY ALGAE

- **RED ALGAE:-** Along with chlorophyll, the red algae also create phycoerythrin, a pigment made of red photosynthetic protein. Due to this pigment's light-harvesting ability, which causes blue light to be absorbed while reflecting red light, red algae acquire their color [31]. Phycobilins containing chromatophores are covalently bound to the protein. These algae species can carry out the process of photosynthesis since the pigment mentioned is present [32]. *Irish moss, Gracillaria spp., Porphyra spp.*, etc. are a few red algae species that are utilized in cosmetics.

- **GREEN ALGAE :-** Chlorophyll, a pigment used in photosynthetic processes, can absorb light energy. This pigment is comparable to the haemoglobin, a red pigment found in red blood cells of humans. It moistens the algae species' exposed surface, giving it oxygen, and keeps it from drying. Additionally, it has anti-inflammatory properties [33]. *Chlorella vulgaris, Ulva lactuca,* and other

varieties of green algae are among those utilized in cosmetics. As a precursor to vitamin A, -carotene produced from Dunaliella salina is employed as colorants and food supplements as nutraceuticals [34].

- **BROWN ALGAE:-** A additional pigment called fucoxanthin can be present in the chloroplast of brown algae. Tyrosinase inhibitory actions serve to minimize or control skin pigmentation, it has anti-inflammatory properties, and it also helps to slow down the natural aging process of the skin by promoting the production of collagen, a structural protein that tends to break down with age. The pigment also maintains the skin moisturized and the skin cells functioning properly [35]. *Isochrysis spp., Postelsiapa maeformis, Laminaria digilata*, and other species of brown algae are some of the ones utilized in cosmetics.

5) Algae in cosmetics

The benefits they have for the skin are well documented for a number of secondary metabolites derived from algae [36]. The cosmetics industry has funded the research and development of new products that incorporate ingredients or extracts from natural sources as a result of a global trend toward products that are viewed as healthful, environmentally sustainable, and obtained ethically. Algae are naturally exposed to oxidative stress, and they develop a number of effective defense mechanisms against reactive oxygen species and free radicals. They also produce compounds that can protect cosmetics from the damaging effects of UV radiation by acting similarly to the organic and inorganic filters that are currently available on the market [37,38]. In fact, when C. *vulgaris*, *Nostoc*, and *Spirulina* platensis are grown in the presence of UV radiation, both chlorophyll and carotenoids are produced more abundantly [39]. *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 [40]. various secondary metabolites of some microalgae can treat seborrhea, block various inflammation processes, and prevent blemishes in addition to repairing damaged skin and maintaining 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 [41–15,28,42–43]. These were listed in accordance with the category of cosmetic product in order to help people understand how algae affects cosmetics.

5.1 Skin whitening and anti-wrinkling:-

Melanin, a complex polymer pigment that gives human skin color and serves as a protective barrier for skin cells, absorbs UV radiation when skin is exposed to it directly for an extended period of time [44]. 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 [38].*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 [45]. 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) [46].Pigments from algae such as fucoxanthin from brown algae *Laminaria japonica*, *Alaria, chorda*, and *Macrocystis* help to reduce the activity of tyrosinase and melanogenesis [47].

5.2 Moisturizers:-

Moisturizing and hydration are very important for skin and are essential to maintaining its healthy texture and elasticity. Polysaccharides play a very important role in cosmetics as moisturizers. These

macromolecules have a high capacity for water storage and can be linked to keratin through hydrogen bonds thus improving skin moisturization. According to Wang and colleagues [48]. Some proteins and their hydrolyzates from genus *Porphyra*, *Spirulina sp*. and *Chlorella sp*. have strong affinity with skin and hair providing moisture retention and suitable viscosity [49,50]. Cosmetics containing algae peptides can be used in products for skin and hair care, skin lotion, face lotion, milky lotion, cream, shampoo, rinse, hair restorer, solution for permanent wave, hair coloring agent, and body soap or bath agents [49,50]. 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 [51]. 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 [52].

5.3 Anti-aging products:-

Skin aging is a complex biological process that refers to the skin losing its flexibility with age, as well as the development of fine lines, ridges, creases, and skin discoloration [53]. Because of the tremendous severity of the harsh environmental variables that our skin is exposed to, conditions like dryness, thinning, skin laxity, fragility, increased pores, and drooping of the skin cause early wrinkles as the elastin fibers slowly degrade [54]. 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. In a recent study, the brown macroalga *Macrocystis pyrifera* was shown to contain the antioxidants phloroeckol and tetrameric phloroglucinol, which are chemically classed as phlorotannins. These phlorotannins may have antioxidant and anti-diabetic properties, which help delay the aging process of the skin [55]. The antioxidant properties of β-carotene found in green and red algae help against skin aging [58]. In order to boost collagen stimulation, anti-aging treatments can contain extracts of *Monodus species*, *Thalassiosira species*, *Chaeloceros species*, and *Chlorococcum species* [56]. Omega-3 and -6 essential fatty acids, which are widely known to support cell regeneration and skin health, are among the many necessary vitamins, minerals, and nutrients found in brown macroalgae's makeup [28]. In skin fibroblasts, free radicals may activate metalloproteinase (MMP), harming the collagens, cell membranes, and cell nuclei. Green algae extracts have the potential to suppress MMP activity and increase the amount of collagen and elastin in fibroblasts, hence preventing UV-induced skin issues such stratum corneum thickening, rough texture, wrinkles, and flaccidity [57]. In topical skin care treatments and even hair protection, extracts of the snow algae *Chlamydocapsa sp*. are used to primarily combat oxidative processes like photoaging. Additionally, it could prevent wrinkle formation following exposure to UV radiation, cold, or dryness [59]. It could also reduce transepidermal water loss (TEWL) and protect against the loss of the barrier function caused by environmental exposure.

5.4 Algae as thickening agent and skin sensitizer:-

If the formulation calls for a high water content, thickening agents are employed to prevent consistency issues in lotions and other cosmetic goods. Polyethylene glycol and vegetable gum are two thickening agents that are utilized in cosmetics [60]. *Gracillaria* and *Gellidium*, two red algae species, contain agar in their cell walls, which serves as a binder. Another type of thickening and stabilizing ingredient is carrageenan, which is produced from the *chondrus crispus* [61]. Due to the presence of skin-beneficial pigments including phycocyanin, proteins, vitamin A, carbohydrates, and carrageenan, some algae species can also be used as skin sensitizers in cosmetics [62].

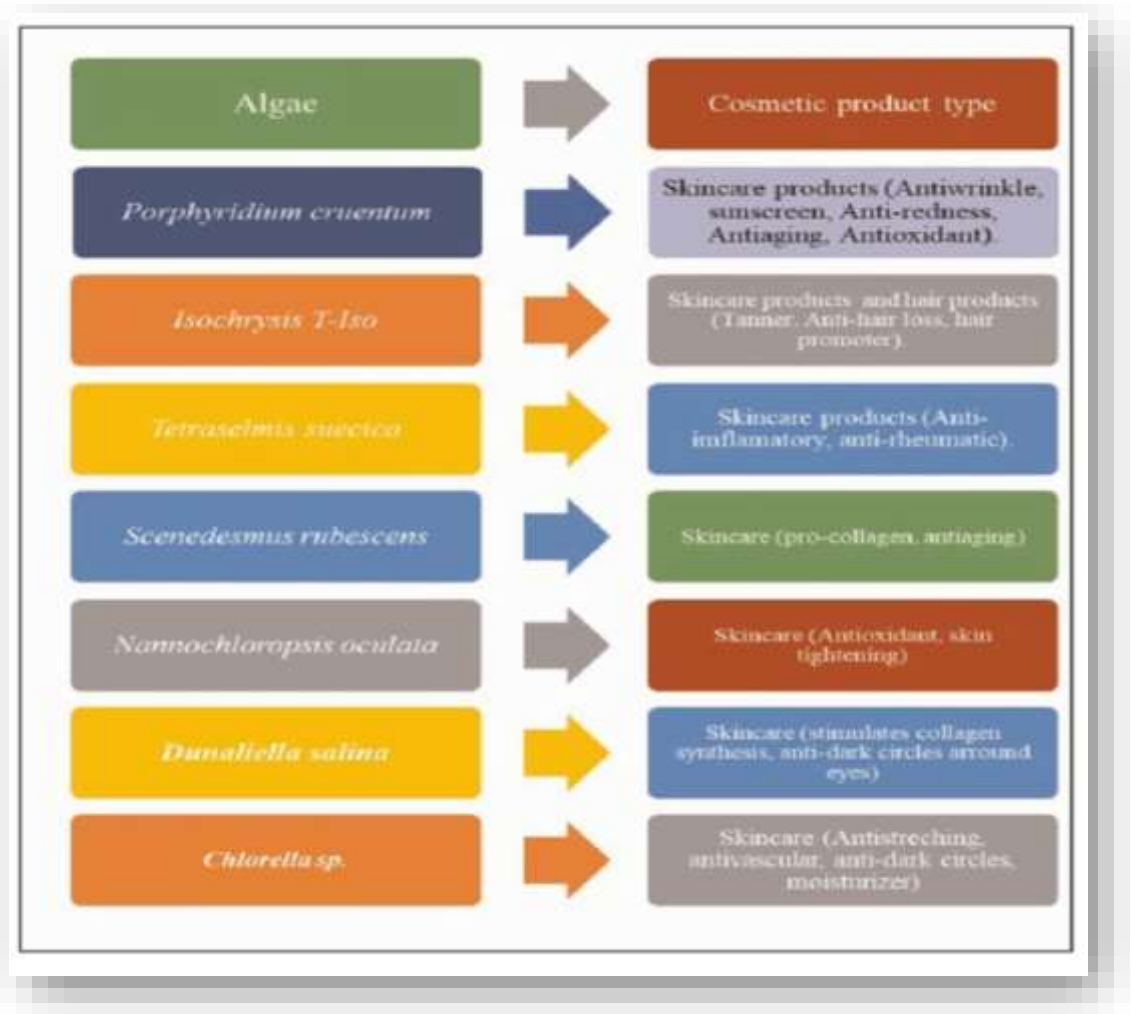
5.5 Algae as antioxidants:-

Antioxidants are substances that help prevent skin damage while transferring electrons to an oxidizing agent to give skin a healthy shine. An antioxidant aids in inflammation reduction, wrinkle reduction,

and skin tightening. Retinoic acid, a form of vitamin A, improves skin suppleness while minimizing wrinkles, dark spots, and dark circles [65]. Retinoic acid is produced by cyanobacteria blooms, it has been discovered [66]. Carotenoids are fat-soluble auxiliary pigments that assist algae in photosynthesis by assisting chlorophyll in absorbing light [67]. Natural antioxidants include vitamins C and A. Vitamins found in algae like *Spirulina maxima* and *Chlorella vulgaris* aid in skin toning, healing of dark circles, purifying skin, and promoting hair development by curing dandruff [68].

5.6 Hair care:-

Monodus sp., *Thalassiosira sp*., *Chaeloceros sp*., and *Chlorococcum sp*. extracts are recommended for formulations to prevent hair loss because they can modulate melanogenesis in hair and human skin, enhancing and stimulating keratinocyte differentiation, melanocyte proliferation, and growth of human hair and hair follicles [56]. Among the cosmetic formulations for sun protection and anti-aging, those containing oil derived by dry weight and containing species of microalgae from the Chlorella genus have demonstrated the potential to soften and flexibilize both skin and hair [63]. Lastly, taking into account the current market, alguronic acid appears as a new topical cosmetic product capable of enhancing skin appearance and health, consisting of a blend of polysaccharides extracted from biomass grown in the dark, under heterotrophic conditions, from *Chlorella protothecoides* (UTEX 31) and *Parachlorella* [64]. Further research to support the product's effect is not yet available, though. We therefore propose additional research on bioactive chemicals to enhance the biological activities of algae, taking into account that the use of algae in cosmetics is a promising topic for the cosmetics sector.



[Fig 3]

6) Algae therapy in skin diseases

There are several skin conditions that can affect people of all ages. There are many different types of skin issues, such as pigmentation disorders, eczema, acne, scars, dermatitis, rash, and others [69,70]. Due to their many bioactive components, algae have been discovered to provide significant skin benefits. The brown seaweed *Sargassum polycystum* has been used to treat skin-related ailments in traditional medicine [71]. The two seaweeds *Sargassum polycystum* and *Padina tenuis* had strong dermal protective effects on human cell lines and had the ability to prevent the growth of human epidermal melanocytes in vitro [72]. Acne treatment against P. acnes and S. epidermidis was accomplished with topical C-phycocyanin ointment derived from *spirulina* [73]. Marine algae have gained a lot of attention recently as excellent sources of anti-inflammatory and anti-allergic compounds [74]. In the treatment of atopic dermatitis, the green alga *Seaweed fulvescens*, which is high in chlorophyll, was effective [75]. The usefulness of *Macrocystis pyrifera* and *Durvillaea Antarctica* algae extracts in treating common herpetic symptoms in humans caused by *Herpes simplex* viruses was demonstrated by their phytotherapeutic effects [76]. In their book chapter, Zanella and Allam [77] examined how algae are used in cosmetics and listed some of the commercially available algal-containing products, as seen in (Fig. 3).

Conclusion

In the search for natural products for cosmeceutical applications, algae offer an excellent choice and are now being commercialized in many products. It is a continuous challenge to increase the consumers' awareness about algae-based skin care products as much safer products compared to synthetic ones. They improve the health of the skin by promoting collagen and serving as anti-aging, antioxidant, anti-inflammatory, and anti-wrinkling agents. Algal species are employed in a wide range of other biotechnological sectors, including those producing biofuels, biofertilizers, dietary supplements, etc. The rising uses of algae in the cosmetic sector are the main subject of this review.

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