

# Role of chlorophyll in cosmeceuticals: an overview

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## Abstract

Chlorophyll is the green pigment within the plant that helps to soak up sunlight and convert it into energy. It's believed that it's beneficial for the human body. These pigments are often differentiated into two types, chlorophyll and B. Algae are oxygenic photosynthetic organisms mainly found in aquatic environments and wetlands and are host to immense biodiversity, including aquatic animals, plants, and microalgae. Microalgae are an assorted group of both single-celled and multicelled microorganisms there are increasing trends in the usage of photosynthetic microorganisms including macro and microalgae in the field of cosmeceuticals by incorporating the bulk products extracted from the biomass into cosmetics formulations. Algae species contain a green-colored pigment recognized as chlorophyll. The main sources of chlorophyll are spirulina, Chlorella Vulgaris, green algae. Chlorella Vulgaris may be microalgae containing chlorophyll as an antioxidant, widely used as active ingredients within the cosmetic industry. Spirulina stands out as sustained bioactive microalgae with health-promoting factors and a very important active ingredient of natural cosmetics products currently it has been incorporated in topical skincare formulations, like moisturizing, anti-wrinkle, antiaging, antiacne, antioxidants, revitalizing, protecting alongside cleaning and shining action both for hair and skin, furthermore microalgae is employed by cosmetics formulators to promote healthy sunscreen protection to treat skin pigmentation disorder and to heal the wound. Nowadays, consumers prefer natural cosmetics because they aren't harmful to the skin. In this review, recent cosmetics formulations containing chlorophyll are revised by their ability to boost skin appearance and promote healthy-looking at the current emergency of the beauty industry, both the starting material and final chlorophyll-based cosmetics products are available in the market, and their current regulations, it's likely that in the coming year diversity quality and topical application, food supplements of the chlorophyll-based product will increase rapidly

## Introduction

The term cosmeceuticals are a consolidation of cosmetics and pharmaceuticals encompassing the biologically active compound retaining therapeutic value. These are assorted various chemical compounds some of which are acquired from natural sources like plants, animals, algae, and minerals, while others are synthetic like sodium lauryl sulfate, PVP, and ethylparaben. Recently researchers, have flipped their interest towards microalgae being the foremost supply of chlorophyll, for the preparation of herbal products such as food and cosmetics. Chlorophyll could be a naturally obtained pigment from algae, green algae spirulina Chlorella Vulgaris. This pigment can be differentiated into two types, chlorophyll A and B. It's been found that chlorophyll is beneficial for the treatment of skincare, haircare improves the skin snap and helps to get rid of wrinkles it provides oxygen to the exposed surface of algal species and prevents it from drying by moisturizing it. It also possesses an anti-inflammatory effect. It will increase procollagen and protein expression in photoprotector skin cells once taken in high doses algae are oxygenic photosynthetic organisms that are principally found in aquatic environments and wetlands. The utilization of algae as a photosynthetic organism is increasing day by day within the cosmeceuticals each macro and microalgae have used the extract of the biomass is incorporated in several cosmetic formulations The first reported scientifically pure algae culture was of Chlorella Vulgaris which was grown by Dutch microbiologist M.J Beijerinck in 1890 Mainly green algae are the major source of chlorophyll there are lots of formulations of green algae is available in the market [ spirulina supplements in tablet form are mainly seen in the market] at the present the demand for spirulina and chlorella based products is high and anticipated to increase at CAGR of 7.1% from 2017 to 2022 (USD 238.3). Furthermore, algae are also a rich source of many other valuable compounds, such as several minerals and vitamins. The most commonly identified minerals are potassium, calcium, magnesium, selenium, iron, and zinc. Among the vitamins, B vitamins are the most abundant. Its presence confers to the algae properties of the DNA repairs, electron transfer, fatty acids synthesis, and one-carbon metabolism [4]

## Aim

Role Of Chlorophyll in Cosmeceuticals: An Overview

## Objectives

1. To succinctly review the recent progress of chlorophyll as cosmeceuticals
2. To study future aspects and present market scenario of chlorophyll infused skincare

To provide an integrated, synthesized overview of the current state of knowledge about the use of chlorophyll in skincare  
Spirulina

Immunity after corona Everyone's immunity depends on food, lifestyle, and exercise. But due to overuse of chemical fertilizers and pesticides, climate change, and fertile soil erosion, there is a shortage of nutrients in food today. Moreover, the question is whether the hunger of the growing population can be met through sustainable agriculture. After in-depth discussions at the 1974 United Nations World Food Conference, many experts agreed that there is a food that could be the best alternative to satisfy the world's hunger in the future. Protein, vitamins, minerals, and antioxidants Spirulina is the name given to this versatile superfood,

which is purely natural and pure vegetarian. This superfood is a kind of algae. "There are puddles of green water in front of our eyes," said algae. Eat algae? Many do not tolerate this idea, but these algae are not simple. Just as some mushrooms are poisonous, edible mushrooms are cultivated. Similarly, edible algae i.e., spirulina is cultivated scientifically. Spirulina is found naturally in the Gulf region, but other species of algae also grow in the spirulina in the bay. Therefore, for the sake of purity, spirulina is always cultivated in an artificial environment Spirulina is cultivated in shallow, elliptical ponds, which are called raceway ponds in the classical language. Spirulina formed in water is filtered, dried, and powdered. This powder is then marketed in the form of tablets or capsules. In some places, spirulina is grown in ponds or wastewater to save on production costs. Such spirulina is available in the market at very low prices, but its consumption is dangerous. Before purchasing Spirulina, make sure it is manufactured at an FSSAI approved manufacturing facility

Spirulina has been produced in India for decades. India is the third-largest producer of spirulina in the world after China and Indonesia. Yet many do not know about spirulina. Spirulina from India is mainly exported to the USA, and Europe There was a lot of research on spirulina by NASA in the 1970s, with NASA agreeing that spirulina is the best food to give to astronauts. The maximum amount of nutrients can be obtained from spirulina in minimum size. Of course, spirulina cannot be eaten as a substitute for a daily meal as there are different concepts of filling and nutrition; But spirulina is a great remedy for nutritional deficiencies Spirulina contains 60 to 65 percent protein, 25 times more vitamin A than carrots, 60 times more iron than spinach, 12 times more vitamins than milk, three times more calcium, vitamin E, zinc, magnesium and eight minerals. The amount of protein in spirulina is pulses; Also, much higher than in non-vegetarian foods. Spirulina is a boon, especially for vegetarians. Many international players regularly consume spirulina.

Spirulina has been declared the most nutritious food on earth by the United Nations. Spirulina is given worldwide as a treatment for malnourished as well as undernourished children and women. The problem of malnutrition is also frightening in India. In the states of Karnataka and Odisha, Spirulina yukta Chikki has been started for malnourished children through Anganwadi. About two thousand malnourished children in the Pune district have been given Spirulina through Integrated Child Development Services Scheme, but these efforts need to be transformed into a larger movement. If the government takes the initiative, farmers will be encouraged to cultivate spirulina [ Article from Maharashtra Times 1/05/2022]

### Chlorella

Microalgae are a crucial part of the early civilization [5] the first reported way back in 2000y to the Chinese who used the microalgae *Nostoc* to survive the famine [6]

Chlorella is the freshwater unicellular, green algae belonging to the family chlorellaceae, whose name is derived from two words," chloros "meaning algae, and the Latin suffix "Ella" meaning small. each cell of chlorella is 2-8 microns thick and doesn't have flagella. chlorella consists of green photosynthetic pigments chlorophyll a and chlorophyll b courtesy to which it is the richest source of chlorophyll available. chlorella consists of 55-66% protein. 1-4 % chlorophyll, 9-18% dietary fibers, vitamins, and minerals[7 ]. among the various species discovered – Chlorella Vulgaris is the most researched til now The first reported scientifically pure algal culture was of Chlorella Vulgaris which was grown by a Dutch microbiologist, M.J. Beijerinck in 1890[8]. By 1919, Otto Warburg published articles on his use of chlorella in the study of plant physiology. After years of extensive research on microalgae, scientists around the world speculated the fact that since microalgae have such high nutritive value, their production on a large scale can revolutionize agriculture for several more years to come. During the 1940s, two researchers named Jorgensen and Convit fed concentrated Chlorella soup to 80 patients in a leper treatment colony in Venezuela. the improvement in the healthiness of the patients was the first documented evidence of the potential of microalgae as a health supplement [8]



### Microalgae

Algae are not only promising as waste converters and recyclers. The algal cell contains many useful substances and microalgae are cultivated increasingly for the production of valuable raw materials. For example, it is possible to produce oil, proteins, starch, and pigments (e.g., beta-carotene). Applications of these materials are numerous, ranging from biodiesel and bioplastics to colorants and hamburgers.

Microalgae also known as blue-green algae or cyanobacteria are prokaryotic, microscopic unicellular algae having an approximate diameter of 1-50  $\mu\text{m}$ . They are phototrophic, but some can also grow heterotrophically. They carry out oxygenic photosynthesis that is quite similar to that found in terrestrial plants, utilizing carbon and light (radiant) energy for their metabolism[9]. They exist individually, in chains or clusters. Microalgae contain phosphorous, calcium, iron, vitamin A, B, C, E, folic acid, biotin, beta-carotene, pantothenic acid, and vitamin B12 [10]. Some microalgal species can adapt to changes when phosphorus is exhausted in the environment; some species of microalgae possess the ability to substitute nonphosphorus membrane lipids in place of phospholipids [11]

Green algae produce photosynthetic pigment chlorophyll, which can 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 an anti-inflammatory effect[12] Some species of green algae used in cosmetics are *Chlorella Vulgaris*, *Ulva Lactuca*, etc.  $\beta$ -carotene obtained from *Dunaliella salina* is used as colorants and food supplements as nutraceuticals as it is a precursor of vitamin A [13]



[This Photo](#) by an Unknown Author is licensed under [CC BY-SA](#) (oil droplet of green algae)

#### Benefit Of Chlorophyll for Skincare Formulations

Chlorophyll has lots of benefits when used in skincare formulations, few research has aimed at studying and demonstrating the chlorophyll healthy effect on the skin. The most cosmetic action supported by the literature and claimed by the market is the anti-age, including moisturizing, antioxidants, and brightening properties, and the antiacne and wound healing, especially shown by spirulina.

#### Skin Moisturizing

Skin aging is a complex process that depends on both an inheritable predilection and external factors and causes functional and structural damage. A moisturizer is made up of a complex admixture of chemical composites that make the skin's epidermis softer. However, it's prone to acne aggravation and can indeed beget eczema, if the skin isn't duly moisturized. Thereby, moisturizers help in retaining the dampness of the skin precluding drying, bruising, and wrinkles. Water moles play a vital job in maintaining the skin's structural properties indeed water binds the dermal proteins, similar to collagen, and assures the tissue thickness, water along with certain acids such as hyaluronic helps in moisturizing skin precluding drying [14].

Studies show how polysaccharides from certain algal species like *S. Japonica*, *Chondrus crispus*, and *Codium tomentosum* help in the absorption of water or moisture, providing a soothing effect. This keeps the skin moisturized in an extremely hot and dry environment [15].

In this context, Delsin et al., 2015 firstly promoted the use of *Spirulina* as an innovative ingredient for dermo-cosmetic products. They showed how the microalga improves the epidermis structure and acts as a hydration booster with positive results on skin barrier function, particularly for skin protection and anti-age, and oil control [16]

To investigate the behaviors of spirulina in the skincare, in 2018 F. Apone et al. tested and compared two Spirulina with the analogous unfermented. The reported data show greater effectiveness of the enzymatically fermented extract in moisturizing and protecting the skin cell [17] Another important aspect related to skin aging is the peptides reduction in the dermis extracellular matrix. Peptides are a short chain of amino acidic residues, which are involved in several physiological processes, such as inflammation, immune response, and skin remodeling, and stimulate the synthesis of structural proteins (collagen and elastin). For this reason, cosmetic products that are rich in peptides may prevent the onset of wrinkles and signs of aging [18].

#### Wound healing

A skin wound is a disruption of intact tissue, which leads to a loss in functional and anatomic continuity. Environmental conditions, accidents but also skin issues like dryness and dermatitis, might be some of the trigger factors. Wound healing is, instead, a complex process involving an inflammatory system, synthesis of structural proteins, migration, and proliferation of both parenchyma and connective tissue cells. Full recovery is complex and, sometimes, chronic disease or bacterial infection may further undermine the healing process.

In 2011, spirulina was investigated for its effectiveness in wound healing, due to its flavonoids and triterpenoids, which act as an astringent and antimicrobial agent [19]. The spirulina wound healing effect of dry extract, obtained in petroleum ether, chloroform, and methanol was tested on rats and monitored for 16 days. Specifically, the wound contraction—as the percentage reduction in wound area—and its closure time were controlled. A significant improvement in the wound healing activity was noticed with the three extracts aforementioned. The best result was obtained in the ointment with Spirulina petroleum ether-based extract at 10% w/w. In 2013, Gur et al. studied the impact of the crude Spirulina extract and the phycocyanin isolated from the crude Spirulina extract on cultures of human keratinocytes, by using in vitro and in vivo models of wound healing [20]. They observed that Spirulina extract showed the best growth stimulation at 33.5 µg/mL dose of treatment, which declared a cell activity ranging from 100% to 270% after 72 h. Cell viability has also improved with phycocyanin and it was measured, even up to 213%. Cell activity and proliferation difference between Spirulina extract and phycocyanin were noted not to be important ( $p > 0.05$ ) at the range of doses (33.5–0.0335 µg/mL) examined. It was also discovered that 1.25% of C-phycocyanin has a superior effect on the in vivo efficiency, compared to other preparations with Spirulina extract, on the 7th day. Overall, the proliferation and growth stimulation activities of Spirulina extract seem to be directly connected to the presence of both phycocyanin and carotenoids, which synergistically contribute to wound healing and tissue regeneration.

More recently a Korean research team absorbed Spirulina in an engineered tissue, to evaluate its wound healing potential. They selected nanofibers of polycaprolactone

(PCL) as a supporting material suitable for tissue regeneration. PCL, which is an FDA-approved polymer, is also biocompatible, biodegradable, and known to favor oxygen absorptivity, drainage capability, and water evaporative control, which are critical factors for skin regeneration. In a study, Spirulina aqueous extract was absorbed on the nanomaterial and the wound regeneration was evaluated using an in vivo wound model. In this specific regard and from a bioethical view, we contest such use of an animal for analysis in the cosmetic field and we strongly recommend the stakeholders find other cruelty-free alternatives to perform efficiency tests. In general, Spirulina-PCL helped to regenerate wounds and enhanced skin regeneration, by improving the antioxidant mechanism against the reactive oxygen species (ROS) of fibroblast under oxidative stress. Nevertheless, the developed nanofibers had a restricted capability to moisturize wounded skin because of the hydrophobicity of PCL. To resolve this issue of the hydrophobic behavior of spirulina PCL nanofibers, the alginate was added due to its high hydrophobicity and absorbing capacity

#### Skin whitening and antiwrinkle

When direct exposure between skin and UV rays is established for a long period, the radiation is absorbed by melanin, a complex polymer pigment that imparts color 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. Skin hyperpigmentation is an aesthetic issue, which raises a growing concern in the current cosmetic market. Currently, whitening products are pivotal in the anti-age skincare routine, since they reduce spots and skin dyschromia caused by

UV exposure, tyrosinase plays an important role in controlling the production of melanin and then in coloring hair, skin, and eyes. This multicopper enzyme facilitates the transformation of L-tyrosine in L-dihydroxyphenylalanine (L-DOPA), which in turn oxidizes itself and becomes DOPA quinone. A set of spontaneous cascade reactions leads to the creation of a pigment polymer, called melanin, which is released to the surrounding keratinocytes. Both the abnormal loss and the overproduction of melanin may generate serious esthetical and dermatological skin disorders in humans, such as Acanthosis nigricans, melasma, Cervical poikiloderma, Lentigines, Periorbital hyperpigmentation, neurodegeneration associated with skin cancer risk and Parkinson's disease. The most reliable strategy to treat such pigmentary disorders so far is to use inhibitors of tyrosinase. Pigments from algae such as fucoxanthin from brown algae *Laminaria japonica*, Alaria, chords, and *Macrocystis* help to reduce the activity of tyrosinase and melanogenesis [23].

Table. Natural blends with inhibitory activity of tyrosinase. Published by Ref and references therein

(table no.1 ) Natural blend with inhibitory activity of tyrosine, published by Ref no.26 and ref therein

Compound	IC50	Substrate
Ethanol extract of <i>Cudrania tricuspidata</i> twig	$1.14 \times 10^{-4}$ g/mL	L-tyrosine
Steppogenin from <i>C. tricuspidata</i>	$2.52 \pm 0.66$ µM/ $7.26 \times 10^{-7}$ g/mL	L-tyrosine
Oxyresveratrol from <i>C. tricuspidata</i>	$2.85 \pm 0.26$ µM/ $6.96 \times 10^{-7}$ g/mL	L-tyrosine
Trans-dihydromorin from <i>C. tricuspidata</i>	$21.54 \pm 0.84$ µM/ $6.55 \times 10^{-6}$ g/mL	L-tyrosine
Quercetin from <i>C. tricuspidata</i>	$54.58 \pm 0.89$ µM/ $1.65 \times 10^{-5}$ g/mL	L-tyrosine
Dihydrokaempferol from <i>C. tricuspidata</i>	N100 µM/N2.88 $\times$ $10^{-5}$ g/mL	L-tyrosine

Protocatechuic acid from <i>C. tricuspidate</i>	N500 $\mu\text{M}/7.71 \times 10^{-5} \text{ g/mL}$	L-tyrosine
Naringenin from <i>C. tricuspidate</i>	N500 $\mu\text{M}/1.36 \times 10^{-4} \text{ g/mL}$	L-tyrosine
Kojic acid (standard tyrosinase inhibitor)	$50.43 \pm 1.75 \mu\text{M}/7.17 \times 10^{-6} \text{ g/mL}$	L-tyrosine
Kojic acid (standard tyrosinase inhibitor)	0.67 mM/ $9.52 \times 10^{-5} \text{ g/mL}$	L DOPA
85% ethanol extract of <i>Hesperethusa crenulata</i> bark	$8.6 \times 10^{-4} \text{ g/mL}$	L-tyrosine
Water extract of <i>H. crenulata</i> bark	$1.09 \times 10^{-3} \text{ g/mL}$	L-tyrosine
Methanol extract of <i>H. crenulata</i> bark	$1.42 \times 10^{-3} \text{ g/mL}$	L-tyrosine
Methanol extract of <i>Magnolia denudata</i>	$3.34 \times 10^{-3} \text{ g/mL}$	L-tyrosine
Methanol extract of <i>M. denudata</i> var. <i>purpurascens</i>	$1.06 \times 10^{-2} \text{ g/mL}$	L-tyrosine
50% methanol extract of <i>Podocarpus elongatus</i> leaves and stem	$4.7 \times 10^{-4}$ and $1.4 \times 10^{-4} \text{ g/mL}$ , respectively	L-DOPA
50% methanol extract of <i>P. falcatus</i> leaves and stem	$2.9 \times 10^{-4}$ and $3.5 \times 10^{-4} \text{ g/mL}$ , respectively	L-DOPA
50% methanol extract of <i>P. henkelii</i> leaves and stem	$3.7 \times 10^{-4}$ and $0.4 \times 10^{-4} \text{ g/mL}$ , respectively	L-DOPA
50% methanol extract of <i>P. latifolius</i> leaves and stem	$4.1 \times 10^{-4}$ and $3.6 \times 10^{-4} \text{ g/mL}$ , respectively	L DOPA
Dieckol from <i>Ecklonia cava</i>	20 $\mu\text{M}/1.49 \times 10^{-5} \text{ g/mL}$	L-tyrosine
Cinnamic acid	2.10 mM/ $3.11 \times 10^{-4} \text{ g/mL}$	L-DOPA
Ferulic acid	0.559 mM/ $1.09 \times 10^{-4} \text{ g/mL}$	L-tyrosine
Caffeic acid	0.037 mM/ $6.67 \times 10^{-5} \text{ g/mL}$	L-tyrosine
Ethanol and water extract of <i>A. platensis</i>	$1.4 \times 10^{-3}$ and $7.2 \times 10^{-3} \text{ g/mL}$ , respectively	L-DOPA

In the last decades, a huge number of natural and artificial inhibitors have been suggested for the production of hypopigmentation pharmaceuticals, anti-browning agents, and skin whitening cosmetics (Table above). Arbutin, kojic acid, and hydroquinone are among the best-known inhibitors, even though their use is currently limited because of certain side effects, among which irritation and allergies.

Indeed, hydroquinone in cosmetic products is also forbidden by the EU and the FDA

As a result, the use of *Spirulina* as a safer and greener tyrosinase inhibitor might have a huge potential application in the field. The effect of *Spirulina* on skin pigmentation was examined in detail by S. Sahin et al., in 2018. They demonstrated that this microalga has a big potential for the inhibition of tyrosinase and might be used for the development of skin whitening cosmetics, totally effective and safe. S. Sahin showed a high inhibitory effect on mushroom tyrosinase activity of *Spirulina*'s extracts. Moreover, the tyrosinase activity was remarkably reduced in a dose-dependent manner. In particular, the IC<sub>50</sub> values of tyrosinase inhibition with *Spirulina* water and ethanol extracts were found as  $1.4 \times 10^{-3}$  and  $7.2 \times 10^{-3} \text{ g/mL}$ , respectively. The values just mentioned were compared with other known natural tyrosinase inhibitors, and were found to be bigger than the IC<sub>50</sub> value of kojic acid (IC<sub>50</sub> =  $2.8 \times 10^{-4} \text{ g/mL}$ )[30]

## Anti-aging and anti-acne

### Anti-aging

Skin aging is a complex biological activity that refers to the loss of elasticity of the skin, appearance of fine lines, ridges, creases, and discoloration of the skin with growing age [31]. 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 lead to premature wrinkles as the elastin fibers slowly undergo deterioration[32]. The natural process of wrinkling of the skin is amplified if there is continuous exposure to 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 to skin aging, and also decrease the risk of skin cancer among the users[33]. The antioxidant properties of  $\beta$ -carotene found in green and red algae help against skin aging. Algal species such as *Turbinaria ornata*, *Ahnfeltiopsis*, *Colpomenia*, *Gracilaria*, *Halymenia*, *Hydroclathrus*, *Laurencia*, *Padina*, and *Polysiphonia* are used as anti-aging agents[34]. Mycosporine-like amino acid (MAAs) protects against UV-A which can cause skin damage and premature skin aging. MAAs are found in *Porphyra umbilicalis* [35].

Another important aspect related to skin aging is the peptides reduction in the dermis extracellular matrix. Peptides are a short chain of amino acidic residues, which are involved in several physiological processes, such as inflammation, immune response, and skin remodeling, and stimulate the synthesis of structural proteins (collagen and elastin). For this reason, cosmetic products that are rich in peptides may prevent the onset of wrinkles and signs of aging. Like most cyanobacteria, *Spirulina* contains several bioactive compounds, notably proteins (53–62%). A large number of peptides have been screened, fractionated, and purified from *Spirulina* extracts and further used in pharmaceuticals and cosmetics applications. For this purpose, in 2006 a French research team patented a dermatological peptide extract of *Spirulina*, claiming positive effects on the stimulation of fibroblast proliferation and the glycosaminoglycans and collagen synthesis. Moreover, a few years later, also Wang Z. et al., presented a study about antiaging peptides extracted from *Spirulina platensis* at the 13th International Congress on amino acids, peptides, and proteins in Vienna.

### Anti-acne

Acne is an epidermis disorder correlated to sebum hypersecretion in deformed follicles, which implies inflammation and comedones formation. The anaerobic *Cutibacterium acnes* (also known as *Propionibacterium acnes*) plays a role in the inflammation process because it hyperproliferation in the sebaceous lipid environment and produces reactive oxygen species (ROS) and pro-inflammatory compounds. Acne disorder affects several people, mostly during adolescence, and it may lead to a lack of self-confidence, resulting in body shame. Since acne-inducing bacteria have shown side effects and increasing resistance to synthetic drugs like tetracyclidrile, many alternative approaches have been explored in the last decades. Among them, the topical applications of cosmetic formulas containing botanicals as safer active ingredients are the more suitable [37]. Currently, the cosmetic market is strongly interested in formulating antiacne products with a special focus on natural active ingredients, in addition to topical medication. For this purpose, 2018 Nihal et al. developed a topical antiacne formulation using *Spirulina* extract rich in phycocyanin protein

### Antioxidant

The antioxidant potential of blue-colored cyanobacteria is of great interest in cosmesis. Pigments can be used as natural colorants in make-up products, like eyeliner and lipstick, and as antioxidant agents, which protect against UV radiation [41]. Indeed, *Spirulina* contains a lot of photosynthetic pigments like chlorophyll and especially phycocyanin, which determine a long-lasting green-blue coloration in cosmetic formulas [43].

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 that reduces dark spots, dark circles, and wrinkles, it also boosts skin elasticity. It has been found that cyanobacteria blooms produce retinoic acid. Carotenoids are fat-soluble accessory pigments that help algae to harvest light in conjunction with chlorophyll to carry on the process of photosynthesis. Vitamin C and Vitamin A serve as natural antioxidants. Algae like *Spirulina maxima* and *Chlorella Vulgaris* contain vitamins that also aids in skin toning, healing of dark circles, purifying skin, and encouraging hair growth by treating dandruff[48].

### Algae species used in cosmetics

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 a natural moisturizing ability which is exploited to the utmost to keep the skin hydrated and prevent drying of the skin cells. Other algal metabolites such as lipids (carotenoids, sterols), phycobiliproteins (phycocyanin), terpenoids, and pigments, contains anti-inflammatory and anti-oxidant activities, along with acting as stabilizing agents in emollients. More effective bioactive compounds can be developed by gaining a better understanding of the algal cultivation method and its genetics[3]

(table no.2) microalgae used in cosmetics

Algal species	Type	Pigment	Fatty acids/ Metabolites	Applications/ Products
<i>Spirulina</i>	Blue-green algae/cyanobacteria	Phycocyanin	Gamma-Linolenic acid, Phycocyanobilin, Phycocerythrobilin	Anti-aging, antiwrinkle, collagen synthesis, anti- inflammatory, nourishing, antioxidant
<i>Isochrysis</i>	Brown algae	Canthaxanthin, Fucoxanthin	Mistic Acid, Oleic Acid	Antioxidant, sun care, soothing agent, anti- irritant [48]
<i>Dunaliella salina</i>	Green algae	Chlorophyll-a, Chlorophyll-b, $\beta$ -Carotene	Palmitic acid, Linolenic acid, $\beta$ - Cryptoxanthin	Antioxidants, smoothing agents, Anti- inflammatory
<i>Chlorella vulgaris</i>	Green algae	Chlorophyll-a, Chlorophyll-b, $\beta$ -Carotene	Palmitic acid Palmitoleic acid, Polysaccharides	Anti-aging, de- pigmentation, moisturizing and thickening agent
<i>Tetraselmis uecica</i>	Green algae	Chlorophyll-a, Chlorophyll-b, $\beta$ -Carotene	Palmitic acid, Stearic acid and vitamin E ( $\alpha$ - Tocopherol)	activity Anti- oxidant, protective
<i>Botryococcus braunii</i>	Green algae	Chlorophyll-a, Chlorophyll-b, $\beta$ -Carotene	Palmitic acid, Stearic acid	Anti-oxidant

#### Market scenario of chlorophyll and its products

In the last few years, there is a growing curiosity among customers on herbal skincare product. Product with natural origin and less side effect are in trends.

Looking at the current microalgae-based products in the market dried whole spirulina is the largest with more than 12000 tonnes of spirulina biomass being products every year, of which 70 percent is produced in China, India, and Taiwan.

As a consists with Transparency Market Research the global nutraceuticals market (which include functional food and beverages ingredients, dietary supplements, and personal care and pharmaceuticals) which was earlier valued at US\$ 182.60 Bn in 2015,

will rise to US\$ 278.96 Bn by 2021, exhibiting a CAGR of 7.3% for this period. On the basis of revenues, functional food ingredients are the leading product segment with a share of over 31% in 2014. As the functional food industry continues to grow, food firms worldwide are focused on developing new functional food and beverages with added ingredients. For instance, the Chlorella ingredients market is poised to register a CAGR of 25.4%, to reach US\$ 700 Mn by 2022. According to another report the global algae product market is projected to reach US\$3,318.1 million by 2022, with a CAGR of 6.7% from 2017 to 2022.

At the present, the demand for Spirulina and Chlorella based products is high and anticipated to increase at a CAGR of 7.1% from 2017 to 2022 (USD 238.3 million).

this is motivated by rise in demand of herbal product with less side effect

#### 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 astaxanthin, 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 no.3) companies using algal product

Company	Product name	Algae	Applications / Product	Reference
Aquarev industries	-----	Red algae	Carrageenan and <i>Kappaphycus alvarezii</i> cultivation, sargassum seaweed powder, seaweed, liquid fertilizer	<a href="http://www.aquarev.in/">www.aquarev.in/</a>
Algatech	-----	Green algae	Supplies astaxanthin, obtained from <i>Haematococcus pluvialis</i> , which is used as dietary supplements, in cosmetics, food and beverages.	<a href="https://www.algatech.com/">https://www.algatech.com/</a>
Nykaa	Iraya algae body serum	Green algae and <i>Spirulina</i>	It moisturizes and conditions the skin, making it soft.	<a href="http://www.nykaa.com/">http://www.nykaa.com/</a>
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.	<a href="https://www.lorealparis.co.in/">https://www.lorealparis.co.in/</a>
La Prairie	Cellular Swiss ice crystal dry oil	Snow algae ( <i>Chlamydomonas nivalis</i> )	Anti-aging cream which contains Swiss snow algae mixed with sea almond oil.	<a href="http://www.laprairieswitzerland.com/">http://www.laprairieswitzerland.com/</a>

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.	<a href="http://aubreyorganics.com">http://aubreyorganics.com</a>
Algenist	REVEAL Color Correcting Eye Serum Brightener	Green algae ( <i>Dunaliella salina</i> , <i>Haematococcus pluvialis</i> )	A concealer that reduces uneven skin around the eye and covers dark circles.	<a href="https://algenist.borderfree.com">https://algenist.borderfree.com</a>
Dove	Dove Regenerative Repair Shampoo	Red algae	It provides nourishment to damaged hair and repairs it, restoring hair strength.	<a href="https://www.purplle.com">https://www.purplle.com</a>
Jenelt	Ultra UV Defence Brightening Cream with SPF 30 Sunscreen	Red algae ( <i>Porphyra umbicalis</i> )	A sunscreen with antioxidants which prevents the skin from UV rays and premature skin ageing.	<a href="http://www.jenelt.com/">http://www.jenelt.com/</a>
Osea	Osea eyes and lips	Red algae ( <i>Chondrus crispus</i> )	It hydrates the delicate skin around the eyes and lips.	<a href="https://oseamalibu.com/">https://oseamalibu.com/</a>

### Conclusion and future aspects

As herein reviewed, chlorophyll is a potential bioactive ingredient, for developing effective and safe cosmetics. In recent years the skin-care benefits of chlorophyll infused products have been investigated by both academics and company researchers. Spirulina contains a set of synergistically acting components, such as peptides, polyunsaturated fatty acids, vitamins, minerals and antioxidant phytonutrients, which provide a full healthy action to the formulation. Several Spirulina extracts/powders and alga-based skin care products are available on the market and this field is expected to further grow in the following years. As a formulating ingredient, Spirulina—*S. platensis* or *S. maxima*, as the major genes—is used as a dry or liquid concentrated phycocyanin-rich blue extract in the luxury products, or as raw powder in the cheaper formulations. A number of topical Spirulina-based formulations claim a large range of behaviors, including antioxidant, revitalizing, remineralizing, moisturizing, protecting alongside cleansing and shining action, for both hair and skin. Therefore, these products might be topically used like a booster of hydration, antiwrinkles, antiaging and antiacne agents. At the same time, Spirulina might be incorporated in skin-care formulations to promote healthy sunscreen protection, to treat skin pigmentation disorders and to achieve wound healing benefits. Despite the recent progress, the topic should be further investigated: other skin benefits, actions or applications might occur and the role of the phytocomplex and its action pathways need a further exploration. In addition, the human health risks (skin-toxicity, allergies, etc.) should also be studied in greater depth to refine cosmetic spirulina-based products in the long-term. For instance, the antibacterial activity of Spirulina might suggest to study how this alga affects the skin microbiome in deeper details. Taking care of skin commensal bacteria, thus avoiding skin dysbiosis, is an emerging topic in both cosmetic and dermatological fields. Skin dysbiosis is correlated to the incidence rate of skin disease, due to the hyperproliferation of some bacteria that normally colonize hair follicles and glands. To conclude, there is a need to pursue research about Spirulina antimicrobial skin activity to further support the use of this microalga for the treatment of skin dysbiosis.

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