‘BLUE’ is the new ‘GREEN’ for Cosmetic Industry

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***Abstract*: Algae (microalgae and macroalgae) are aquatic photosynthetic organisms largely used due to the variety of bioactive compounds in their composition. Macroalgae have already caught the attention of food, cosmetics, pharmaceuticals and nutraceutical industries. The application of microalgae in cosmetic products have recently received more attention in the treatment of aging, tanning, prevention of rough texture, skin flaccidity, skin whitening and pigmentation reduction. This has allowed microalgae culture to become one of the modern biotechnologies. The variety of cosmetic formulations using biocompounds or algae extracts as moisturizing or thickening agents or stabilizers have been used increasingly since they also provide the desired safety from environmental resources. Although the cosmetic effect of some of these compounds have been already described in many recent publications and journals, but the majority of biomolecules in algae species have not been yet studied and therefore are not yet used in cosmetics. Besides that, various patents have been registered regarding the beneficial effects of algae extract in many cosmetic products but they don’t explain the type of different algal species that are present in the product. Also the effect of particular biocompound on different cosmetics are not mentioned in the patented products. Thus, the customers are unaware of the real description of actives present in the product. Hence this review article gives an idea of all the biocompounds of algal species that are specifically used in particular cosmetics’ formulations along with their specific activity to the product that gives potential for new researches in near future.**

***Keywords*: Biocompounds, Cosmetic products, Microalgae, Macroalgae species**

I. INTRODUCTION :

Ocean seawater is an environment where numerous organisms develop, some of which have been exploited for years to obtain cosmeceutical benefits. However, marine biodiversity is so vast that it will take many more years to be fully explored. Over the last few decades, researchers of natural product have now turned their attention from Green to Blue actives from marine environment which have rich source of plants, animals, micro-organisms which produces a large variety of primary and secondary metabolites. Amongst these, bacteria and algae constitutes a major source of active ingredients**.[1]**

Algae covers a wide range of organisms from different phylogenetic groups with approx. 30,000 species described**.[2]** In general, they can be categorised as multicellular macroalgae and unicellular microalgae. The algae are not closely related in our evolutionary sense, and the phylogeny of the group remains to be delineated**.[3]** Macroalgae usually includes seaweeds while microalgae includes red (Rhodophyceae), green(Chlorophyceae), and brown (Phaeophyceae) algae**.[4]**

Algal cells can transform solar energy into chemical energy through photosynthesis process. Chemical energy is stored in the form of chemical compounds with particular biological activities named as ‘bioactive compounds’. However, there is not much information about bioactive compounds for most of the marine species. Although the principle research into bioactive compounds from marine environment has stemmed from studying macroalgae, recently this research has extended into microalgae as it is easier to cultivate**.[5]** Also, they are capable of producing bioactive compounds with potential applications in cosmetic industry. Such applications are related to anti-oxidants, moisturizing agents, thickening agents, stabilizing agents etc. Not only does microalgae offer great potential in combating the signs of aging, it also has powerful anti-microbial properties which prevent and cure infections. Also it has skin lightening properties that offer great potential for skin whitening and treatment of skin pigmentation conditions, including skin mottling associated with UV exposure and aging**.[6].** Also, they can be used as nutraceuticals, additives and preservatives**.[7]**

The production of cosmetics containing microalgae and other bioactive compounds for anti-aging, sunscreens are in great demand. But nowadays, the industry is focussing on other skin care and hair care products along with. This review thus aims at describing various species of microalgae that are particularly used in specific cosmetics with their mechanism of action.

Micro algae and Macro algae

Microalgae are also called phytoplankton that are very small plant like organism without roots or leaves. They occur in both freshwater and seawater. Most species contain chlorophyll, use sunlight as an energy source and convert carbon dioxide into biomass. In this process of photosynthesis, the algae produces oxygen. On a global scale, microalgae produces more than 75% of the oxygen required for animals and humans**.[8]**

Earlier microalgae cultivation [Fig (a)] was developed in open ponds and photobioreactors such as membrane photobioreactors, horizontal, vertical or heliocolidal tubular reactor, flat-plate reactors.**[9,10,11]**

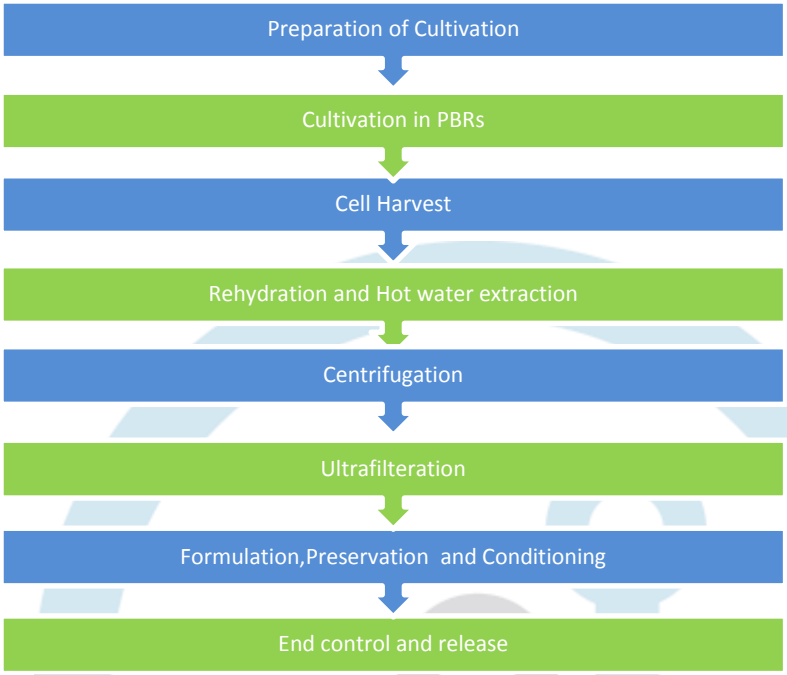

Fig (a) Cultivation of Microalgal species

Recently, the advancements in microalgae cultivation has took place using agro-industrial waste and development of coupled system (Bioreactors-membrane photobioreactors and coupled membrane photobioreactors C-MPBR) brought significant promises to improve the volumetric productivity of cultivation system.**[11]**

However, only a few species of microalgae have been studied and used in some commercial applications, including *Spirulina, Chlorella, Haematococcus, Dunaliella salina., Phaeodactylum, Poryphyridium, Rhodococcus, Anabaena, Cryptomonas, Isochyrsis, Nannochlorpsis, Mastocarpus stellatus, Bracteacoccus, Neochloris*.**[12]** For example, colorants for cosmetic formulations such as eye-shadows, face-makeup, and lipstick are currently obtained from red microalgae.

Macroalgae is a collective term used for seaweeds and other benthic (attached to the bottom) marine algae that are generally visible to the naked eye. Macroalgae take a wide range of forms, ranging from simple crusts, foliose (leafy), and filamentous (threadlike) forms with simple branching structures, to more complex forms with highly specialised structures for light capture, reproduction, support, flotation, and attachment to the seafloor**[13]** These plants have been used for food and as soil conditioners for centuries, with industrial application of extractives a relatively recent innovation generally limited to the more developed areas of the world.**[14]**

II. FUNCTIONS OF ALGAE :

Antioxidants, inhibit melanogenesis, provide UV radiation protection, immunomodulator, control of cutaneous bacterial flora, anti-aging, anti-wrinkle, anti-viral, anti-tumour, skin repair, skin-hydration, gelling and stabilizer. Algae contain different types of pigments, which are specific to particular groups: the green, brown, red, and blue-green algae.

- Marine microalgae contain up to 0.2% of carotenoids. They are powerful antioxidants thanks to their ability to quench singlet oxygen, to be oxidised and to be isomerised. The main sources of carotenoids are microalgae that belong to the Chlorophyceae family. *Dunaliella* has the highest content of b-carotene, and *Haematococcus pluvialis* accumulates the highest levels of xanthophylls (astaxanthin)**[15]**

- Among phenolic compounds isolated from algae, phlorotannins are one of the most important naturally occurring secondary metabolites with a wide range of functional and bioactive properties. Phlorotannins are composed by oligomers of phloroglucinol (fucols, phlorethols, and eckols). They have demonstrated multiple biological activities such as antioxidant effect, free radical scavenging, anti-inflammatory, and hyaluronidase inhibitory activities (Eisenia bicyclis).**[16]**

III. TYPES OF ALGAE IN COSMETICS-

- All Algae are rich in compounds that are of specific use in the cosmetic industry, such as polygalactosides, fucose polymers and ursolic acid. Polygalactosides react with the protective outer surface of the skin and the Ion-ion interaction form a protective moisturizing complex, while the fucose polymers are hygroscopic and act as hydrating agents and the ursolic acid can help form a protective barrier on the skin.**[17]**

- **Fucoidans:** Many different types of macroalgae and mircoalgal blends have been used in cosmeceutical formulations for many decades due to their emollient, viscosity controlling and skin conditioning properties, as well as their inherent stability, bioactive properties, physical and natural marine source. One such group of compounds that promises for use in cosmeceutical products are fucoidans. Fucoidan or 'fucan' is a type of highly branched polysaccharide which is mainly found in various species of brown algae (Phaeophyta) such as *Laminaria japonica*, *Fucus vesculosus*, *Undaria pinnatifida*, *Cladospiphon okamuranus*, and *Hizikia fusiforme*.**[18]**

- **Carrageenan**: Carrageenan is a generic name for a family of hydrophilic polysaccharides with extremely effective thickening and gelling properties. It is used in numerous health and beauty products to provide texture and consistency. Carrageenan is a sulphated galactans and is obtained by extraction from *Chondrus crispus* (Irish moss), a species of red algae (Rhodophyta), and closely related species, *Gigartina*, *Eucheuma* and *Hypnea*. A particular advantage of carrageenan gels is that they are thixotropic. It can produce a range of textures for creams, lotions, sticks, sprays, and foams. The cosmetic industry depends heavily on carrageenan in commonly used products such as soaps, shaving foams, and body lotions.**[18]**

IV. BENEFITS OF ALGAE IN COSMETICS:

How can something widely known as "pond scum" lead to cleaner, healthier skin and hair? Yet algae and its derivatives are increasingly marketed in soaps, shampoos, creams, powders, anti-aging and many other cosmetic products. A diverse group bioactive substances like terpenoids, carotenoids, tocopherol, phenolic compounds, polysaccharides (fucoidan, caragennans, alginates and agar), unsaturated fatty acids, mycosporine-loke amino acids and unsaturated fatty acids derived from marine algae are potential ingredients for cosmeceuticals**.[19]** Algae isn't considered a conventional beauty ingredient,but it has been used in skin care for thousands of years. It's been dubbed as a 'miracle ingredient' and the ' ocean's most potent secret'. There are even entire skin care lines and brands dedicated to using algae and other marine extracts.

In skin Care:

- Micro and Macro algae are found in skin care and boast numerous benefits. It has the ability to instantly hydrate and condition the skin.**[20]**
- Has anti-oxidant property due to presence of numerous phytoconstituents
- Skin types that are benefited most from algae infused products are dry skin, senstive skin, and those who want to combat and preven signs of aging.
- They are also used in environmental applications such as wastewater treatment, biofuel production,Carbon dioxide desquestration and oxygen release to the atmosphere,contributing to the reduction of greenhouse gas effects.**[21]**

In Hair care :

- serves as a gentle clarifier, removing styling product residue, excess oil and other impurities in shampoo.
- Algae extract helps fight hair loss by reducing scalp inflammation caused by bacterial infections.
- promotes hair growth and makes it shine and high in volume.

V. DISTINCT ALGAE USED IN COSMETICS:

1. In Anti-Aging Products :

Skin aging is a slow and complex process including intrinsic and extrinsic mechanisms inducing many changes such as thinning, dryness, laxity, fragility, enlarged pores, fine lines, and wrinkles. Compared to terrestrial plants, microalgae are rich in Vit C, and E, antioxidants and immunologically effective compounds, which are essential for cosmetic product developments.**[22]**

- Microalgae such as *Chlorella*, *Dunaliella*, and *Arthrospira* appear to act on the epidermis to erase vascular imperfection, boost collagen synthesis, and possibly prevent wrinkle formation.**[23]**

- Sulfated Polysaccharide from the red microalgae *Porphyridium* appear to be an excellent candidate to substitute hyaluronic acid as a biolubricant and exhibited antioxidant activity against the auto-oxidation of linoleic acid and thereby preventing skin ageing.**[24]**

- *Pyropia yezoensis* (red algae), have numerous biological functions, including antioxidant, antitumor, anti-fatigue, and anti-inflammatory activities and have been examined for its anti-aging function by promoting collagen synthesis in human dermal fibroblasts.**[25]**
- *Porphyra-334* and *shinorine* from *Chlamydomonas hedleyi* (a green microalgae) act as anti-aging factors by modulating the expression of genes associated with aging in the skin, such as procollagen C proteinase enhancer (PCOLCE) and elastin.**[26]**

- *Asparagopsis armata***,** a red algae that improves elastin skin tissues, reduces fine lines and wrinkles and also acts as powerful antioxidants**.[27]**

- *Sulfated Galactan* from Red Algae can be used to repair cell damage, protect DNA and help prevent premature ageing.**[27]**

2. Algae species in Moisturizing Creams:

- *Asparagopsis armata* has inherent moisturising, strengthening and healing properties for the skin. It improves elastin skin tissues, reducing fine lines and wrinkles. It helps detoxify skin, stimulates skin cell growth and helps skin retain its natural moisture balance.**[28]**

- *Nostoc commune* moisturizing serum is non irritating to skin, provides significant comfort and softness without greasiness, and has significant moisturizing, anti-inflammatory, whitening and nourishing effects for skin.

- *Fucus vesiculosus L.* is a brown seaweed that has got good soothing, emollient, moisturizing and skin smoothing properties**.[29]**

- 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.**[30]**

- Microalgae of the genus *Nannochloropsis* are of particular interest due to their high content in linolenic acid thus having the ability to restore transepidermal water loss (TEWL) and thereby moisturizing the skin.**[31]**

- *Okinawa Red Algae* is a rich source of natural polysaccharides with a proven ability to enhance skin's barrier function, replenish the skin's natural water reservoir, and increase its moisture-retention capabilities.**[27]**

3. Algae species for Sunscreens:

- Scientists found a substance, contained in Rhodophyta (red algae) and many other marine invertebrates including cyanobacteria, fungi, yeast, coral, and so on that provides protection for the organisms against UV light radiation by absorbing the UV-A. This substance is called Mycosporine like Amino Acid (MAA) which is obtained from *Porphyra umbilcalis*. This molecule is water-soluble and secondary metabolites that can absorb UV light radiation with absorbance between 310 and 360 nm. Most marine organisms lived in intertidal and epipelagic zones are having the highest level exposure of UV light radiation. The mechanism works as antioxidants and repair system for their DNA due to UV-A radiation.**[32]**

- In *Nosctoc flagelliforme*nm ,a terrestrial cyanobacterium from arid environments exposed to intense solar radiation have complementary absorption of UV-B by MAAs and UV-A by scytonemin, thereby providing protection over the whole UV radiation range from 280 to 400nm.**[33]**

- MAAs from microalgae such as *Spirulina, Chlorella and Dunaliella* are also known to reduce UV-induced damage. MAAs from algae thus have anti-photoaging activities and can inspire applications as skin care products.**[34]**

4. In Skin Whitening Products:

There is a great demand for whitening cosmetics for the care of lentigo, pregnancy mask, residual hyperpigmentation or hyperpigmentation following medicine poisoning. Tyrosinase is the key enzyme of melanin synthesis. Inhibitors of this enzyme are actively sought. . In recent years, research focused on the discovery of new marine microorganisms derived skin-whitening compounds. It is known that skin whitening is in practice around the globe with Asia as its largest market. Tyrosinase inhibitors are found to be the most common approach to achieve skin hypo-pigmentation, as this enzyme catalyzes the rate-limiting step of pigmentation.**[27]**

- *Ascophyllum nodosum*_Extract is a skin whitening active ingredient through marine glycobiology science and is a purified fucoidan-polyphenol complex, extracted from the brown algae, *Ascophyllum nodosum*.**[35]**

- The brown macroalga *Halidrys siliquosa* has antioxidant and sunscreen activities were 449 found to be equivalent to several commercial antioxidant molecules and to some synthetic UV filters. 450 Moreover, the correlation found between antioxidant activities and total phenolic content supports the 451 involvement of phenolic compounds in the antioxidant mechanisms.**[36]**

- *Astaxanthin*, which belongs to the carotenoids family, also presents interesting depigmentation properties. It would provide a protection for skin from age spots by reducing melanin production by 40% .**[37]** Nostoc commune Vauch has high anti-oxidative activity.**[38]**

5. Algae species for Anti-cellulite Products:

- *Laminaria digitata* is a brown algae which is used mainly in treatments against cellulite and obesity, either alone or combined with other extracts to enhance its activity.The mineral salts and especially iodine stimulate the general metabolism and cause an increase in the osmotic exchanges thus bringing about elimination of the excess fluids. This phenomenon is made use of in the treatment of cellulite and obesity, which is why Laminaria extracts are used in preparations for massage and baths as co-assistants in such treatments.**[39]**

- *Fucus vesiculosus* contains abundant non-essential and essential amino acids such as proline, glycine and lycine all of these which are found in the elastic fibres of the skin. With this in mind, these ingredients alone would be helpful for the skin's elasticity by increasing hydration and thereby maintaining and improving the skin's elasticity.**[40]**

- *Ecklonia cava* can be used as an effective brown algae. It smoothes uneven skin and eliminates excess fats and cellulites from the body.

6. In Skin Cleansers and Sheet Mask:

- *Chlorella vulgaris* and *Spirulina* extract are used in facial cleansers to detoxify the dirt and pollutants from the skin surface because they are excellent source of methyl-cobolamine and poryphrins that possess metal binding capacity.**[41]**

- *Carrageenan* obtained by *Chondrus crispus*, is another kind of thickening and stabilizing agent for face sheet mask.**[42]**

- *Sargassum filipendula* is a type of seaweed that can be used in face masks. It has natural cleansing and hydrating properties. **[43]**

- *Lithothamnium calcareum* is a Red seaweed which is rich in minerals, it restores skin tone, cleanses and detoxifies.

7. In Shampoos:

- *Fucus serratus* is a brown algae which contains large amounts of vitamins, minerals and trace elements, which strengthen and revitalizes the hair.**[44]**

- *Ulva lactua* contains high amount of proteins that helps to strengthen the roots of hair and provides nourishment to the hairs.**[45]**

- *Laminaria japonica* and *Undaria pinnatifida*, also brown algae, have significant anti-inflammatory activities without serious toxic effects at moderate doses. These anti-inflammatory activities are related to treatment of hair loss, because scalp inflammation is one of the causes of hair loss.[46] Thus they can be incorporated in Shampoos.

- *Chlorella* is believed to stimulate the production of keratin, which is the primary component found in hair. Its elements also contains sulfur increases the hair's growing phase, and this results in shinier, longer, and stronger hair.**[47]**

- *Arthrospira platensis* (*Spirulina* Cold Water Infusion Extract) *Spirulina* is a high-protein algae used to increase hair volume and dismiss dry flakes. Brimming with botanical treasures, this powerhouse plant can bring balance to scalp and hair will help return its natural, lustrous condition.**[48]**

8. In Hair Colorants and Hair Mask:

- *Porphyridium cruentum* is the most commonly used species for phycoerythrin production that can be added in hair colours due to their long lasting properties.**[49]**

9. In Anti-Acne Products :

- *Ecklonia kurome* has Antibacterial activity against Propionibacterium acnes. They are also anti-inflammatory.**[50]**

- An O/W (oil in water) emulsion prepared with a phlorotannin-enriched fraction obtained from the brown macroalgae *Halidrys siliquosa* shows antibacterial capacity against *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Escherichia coli*.**[51]**

10. Coloured Make-up Preparations :

- *Chondrus crispus* is a red seaweed used as an emulsifier and thickeners**[52]** and thus can be used in Mascaras , Eye shadows and Foundations. It increases slipperiness which makes cosmetic distribution easier and improves its durability**[53]**

- At present carotenoid production from microalgae refers to astaxanthin and β-carotene from *Haematococcus pluvialis* and *Dunaliella salina*, respectively. These coloured pigments are added in many colour cosmetics.**[54]**

- *Porphyridium cruentum* is the most commonly used species for phycoerythrin production used in lipstick and eyeliners.**[55]**

- Phycocyanin is a blue pigment derived from blue green algae *Spirulina platensis* are used as coloring agents.**[56]**

Various Alage species used in general cosmetic products give skin care, oral care and hair care benefits which is mentioned in **Table 1** below. Different Cosmetic companies uses algae in their product without mentioning their respective species. The list of such companies have been mentioned in **Table 2** below

Table 1: Algae used in general cosmetics

Sr No.	Algae Species	Specific Activity		Cosmetic/Product Activity
		Bioactive Compound	Its Specific Activity	
1.	*Laminaria japonica*	Sulphated Polysaccharides[57]	Skin Moisturizing effect(58)	Moisturizing Cream[58]
2.	*Chlorella vulgaris*	Chlorophyll-a, Chlorophyll-b, β-Carotene Pigments and Polysaccharides[59]	Thickening agent [59]	Anti-aging, de-pigmentation, moisturizing creams[59]
3.	*Rhizoclonium hieroglyphicum*	–	Moisturizing Effect[60]	Moisturizing Cream[60]
4.	*Fucus serratus*	Fucoidans	Protecting agent(reduces gingivorrhagia)[61]	Toothpaste[61]

5.	*Hizikia fusiforme*	Polyphenols and Phlorotannins [62]	Whitening agent[61] Anti-inflammatory[63]	Skin Whitening creams[61]
6.	*Ulva lactuca*	Chlorophyll-a, Chlorophyll-b, Oligosaccharides[61]	Moisturzing and Anti-Inflammatory agent[61]	Anti acne and skin care products[61]
7.	*Poryphyra tenera*	Polyphenols, Phlorotannins, Fucoxanthin[64]	Photo Protection activity [61]	Sunscreens and Sun care products (61)
8.	*Pelvetia canaliculata*	Terpenes and Polyphenols(65)	Hair Moisturizing agent(66)	Hair creams (66)
9.	*Carageenans*	Polysaccharides(67)	Ability to bind water to form gel and stabilize emulsions(67)	Bath and shower gels Shampoo(68)
10.	*Alginates* and *Chondrus Crispus*	Polysaccharides(67)	Emulsifying and gelling agents(67)	Lipstick(68)
11.	*Postelsiapal maeformis*	Chlorophyll-c, Fucoxanthin(69)	Anti-oxidant and Anti-inflammatory agents(70)	Anti-wrinkle cream and Nourishing creams(69)
12.	*Ascophyllum nodusum*	Fucoxanthin, Alginates(71)	Anti-ageing and Smoothing agent(71)	Anti-wrinkle cream and Anti-inflammatory(71)
13.	*Isochyrsis*	Cantaxanthin and fucoxanthin pigment(72)	Anti-Oxidant and Anti-irritant(72)	Sunscreen, Soothing, preparations(72)
14.	*Spirulina platensis*	Vitamin A and C (73)	Antioxidants Moisturizing agent(73)	Anti-aging, de-pigmentation, skin toning, healing of dark circles, purifying skin(73)
15.	*Tetraselmisuecica*	Chlorophyll-a, Chlorophyll-b, Vit E(74)	Anti-oxidant, Protective activity (74)	Used in Sunscreens(74)
16.	*Botryococcus braunii*	Chlorophyll-a, Chlorophyll-b, β-Carotene, (75) Linear alkadienes(76)	Anti-oxidant(75)	-
17.	*Mastocarpus stellatus*	Sulfated polysaccharides(77)	Stabilizing agent(78)	Toothpaste and lotions(78)

Table 2: Cosmetic Products Using Algae :

Product Name	**Type of Algae**	**Application/Product description**	**References**
Hydro Algae Blue	Blue Algae	Moisturizing And Nourishing Cream	**[79]**
Purifying Face Wash	Ocean Algae	Deep Cleansing and moisture Balance	**[80]**
Pure Clay Mask	Red Algae	Exfoliate and refine pores	**[81]**
Advanced Marine Biology Eye Gel	Brown and Green Algae	tighten, boost collagen production and relieve water retention.	**[82]**
Age erasing moisturizer	Green Algae	Rebuild collagen and improves texture and tone of skin	**[83]**
Algae body serum	Green algae and Spirulina	Moisturizes and conditions the skin, making it soft.	**[84]**
Regenerative Repair Shampoo	Red algae	It provides nourishment to damaged hair and repairs it, restoring hair strength.	**[85]**

Colour Correcting Eye Serum Brightener	Green algae (Dunaliella salina, (Haematococcus pluvialis)	A concealer that reduces uneven skin around the eye and covers dark circle	**[86]**
Hair Rescue Conditioning Mask	Blue Green Algae	helps in strengthening of hair and prevents breakage and split ends.	**[87]**

V. CONCLUSION AND FUTURE PROSPECTIVE:

Algae are the undisputed treasures of the sea. The potential applications of natural molecules derived from the Blue world promises a bright future for the cosmetic industry that is constantly looking for innovation. However their complete potential is far being completely exploited. The growth of Algae market can be improved by using feasible and eco-friendly advanced algae production techniques. Also, these algae extracts can be studied for their potential of delivery to the human skin and hair through latest nanotechnologies. The description of various species of algae allows the researchers to evaluate different profiles of algae extract and helps to give an idea about their potential use in various other cosmetic products.

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