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Algae and its Potential Applications in Cosmetology

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ABSTRACT: A, eukaryotic photosynthetic organism, found in diverse locations such as ponds, lakes, ocean to hot springs, glaciers and ice sheets. Recent decades have witnessed a great usage of algae in many industries and have received great attention in many sectors of industry. Recent concern regarding the hazards of chemical usage in many cosmetics thrived a path for introduction of algae in many industries mainly in cosmetics. Algae have potential application cosmetics. Many bio active compounds from algae such as polyphenols, polysaccharides, carrageenan, mycosporine like amino acids, phycocolloids, vitamins etc. Production of many cosmetics products from the algae extracts is prominent. These algal extracts or products have a potential ability to reduce skin ageing, skin tightening, and increase skin lightening. They can also act as a thickening and stabilizing agent. This review article will discuss about the algae its types bioactive compounds, its applications

KEYWORDS: Algae, Antioxidant property, bioactive components, Cosmetics, Freshwater algae, Marine algae, Sun protection factor

I. INTRODUCTION

Chemical sunscreens which are available in the market are incorporated into moisturizers, lotion creams and hair tonics. For the prevention of negative effects of sun exposure, a sunscreen's ability to block harmful ultraviolet radiation is more important. Ultraviolet (UV) radiation is defined as that portion of the electromagnetic radiation that lies between X-rays and visible light which is from 200 to 400 nm [1].

Algae have been recently considered as potential sunscreen resources because of their absorption in the UV region and their antioxidant activity [2]. They have received great attention as photo protective agents due to their unique and exclusive bioactivity. Photo protection is the biochemical process that helps organisms cope with molecular damage caused by sunlight. The significant misfortune in this stratospheric ozone layer and ensuing expansion in UV radiation on the earth's surface has expanded the interest in looking for regular natural photo protective compounds from marine as well as freshwater environments. A number of photo protective compounds such as mycosporine-like amino acids (MAAs), scytonemin, carotenoids and several other UV absorbing substances of unknown chemical structures have been identified from different organisms [3].

ALGAE

Algae are a varied category of photosynthetic eukaryotic organisms that are polyphyletic, indicating organisms are not often closely connected. Includes organisms range from unicellular microalgae, such as chlorella and the diatoms, to multicellular forms, such as the giant kelp [4]. Most are aquatic and autotrophic and lack many of the distinct cell and tissue types, such as stomata, xylem and phloem, which are found in land plants. Seaweeds are the largest and most complex marine algae, whereas the Charophyta, a category of green algae that includes Spirogyra and stonewort, are the most complicated freshwater algae [5]. The majority of algae dwell in fresh or saltwater, where they can either float freely (planktonic) or cling to the bottom. As long as there is enough moisture, algae can grow on rocks, dirt, or vegetation. Lichens are formed when a few algae create intimate relationships with fungi. All algae contain a pigment called chlorophyll a and they make their own food by photosynthesis. The chlorophyll is contained in the chloroplasts and gives many algae their green appearance. However, some algae appear brown, yellow or red because in addition to chlorophylls they have other accessory pigments that camouflage the green colour. Some algae have economic importance because they are a source of carotene, glycerol, and alginates and can be converted into a food source for aquaculture [6]. They are also known as the powerhouse of nutrients, minerals that can help draw toxins from the skin, antioxidants and peptides. It is an outstanding ingredient for skin health. It's high in natural polysaccharides, which

have been shown to improve skin's barrier function, replenish the skin's natural water reservoir, and boost moisture retention. Sulphated polysaccharides (carrageenan), peptides, carotenoids, and fatty acids are all abundant in it [7]. Red algae's strong antioxidant content has been demonstrated to protect against premature skin ageing in studies [8].

CYANOBACTERIA

Cyanobacteria are prokaryotic photosynthetic bacteria, mainly found in lakes, ponds, wetlands, rivers, streams etc. They can be present at a wide range of temperatures. Cyanobacteria have ability to capture sunlight with the help of chlorophyll a and various other pigments. They are formerly classified as blue green algae, they lack membrane bound organelles [9]. Cyanobacteria also have a wide range of enzymatic reactions such as superoxide dismutases also have DNA damage repair systems which help to repair the damage caused by UV radiations. They also prefer alkaline condition especially during blooming, under this conditions inorganic carbon will be in carbonate form which is unavailable for other eukaryotic algae. They have complex folded circular DNA that is in multiple copies.

RED ALGAE

Red algae also known as Rhodophyta are considered as one of the oldest eukaryotic groups in the world. Red algae are abundant in marine habitats but relatively rare in freshwater. Phycoerythrins are phycobilin (light seizing bilins) pigments which give red colour to algae. Red algae is a vast assemblage of 6000 species, mostly found in marine habitat and multicellularity [8]. The red algae have primary plastids or chloroplasts which are derived from cyanobacteria [10]. Red algae exhibit more molecular divergence than kingdom fungi and also exhibit an eccentric reproductive approach [11].

GREEN ALGAE

Green is a heterogeneous group, which are photoautotrophic. They are filamentous and plant-like, found abundantly common in freshwater and terrestrial environment. Green algal are mostly microscopic, rarely a metre long. Green algae can be coccoid, motile, non motile, flagellated, unicellular and multicellular [12].

MARINE ALGAE

About 71 % of the world is covered by the ocean and this ocean provides a domain for all marine creatures. The diversity they have is not accountable [13]. The primary producer in the marine food chain, they are considered as a traditional food of Asian, typically Japan and Korea, they have been using this from ancient times. Seaweed or algae is consumed as both soup and snack. These marine algae are highly rich in bio active secondary metabolites mainly sulfated polysaccharides and polyphenols. They can be found in different sizes and shapes. The size of the algae varies from 0.2- 2.0µm diameter picoplankton to 60m in length giant kelp, it can be unicellular/multicellular; can be in colony, filamentous. They can even have parenchymatous or pseudoparenchymatous structures. There are mainly 4 types of marine algae: Chlorophyceae, Phaeophyceae, Rhodophyceae, blue-green algae.

MICROALGAE

Microalgae are the tiny microscopic photosynthetic organisms consisting of blue green algae, cyanobacteria and protists. Microalgae have short generation time and multiply in a large number within a short period of time [14]. These microalgae are used as food in early Aztecs civilization in Mexico [15]. The first research on microalgae was done at the end of the 19th century [16]. Microalgae are now used for biofuel production [17], entrapment of CO₂ emission [18], and wastewater remediation [19].

SUN PROTECTION FACTOR

Sun protection is considered as an important one as most sun rays consist of 5% of UV rays. The UV rays are dangerous to skin as these rays can cause many serious illnesses such as skin cancer. Melanin present within the skin is a natural UV ray's fighter. Melanin will protect the DNA from UV [20]. Sun screens are chosen based on the SPF or Sun Protection Factor. SPF is the most important data to quantify the effectiveness of sunscreen, being universally



accepted. This method is based on determining the minimum erythema dose (MED), defined as the smallest amount of energy required for triggering the erythema, in areas of protected and unprotected skin [21]. The SPF value is then calculated as the ratio between the MED of protected skin and unprotected skin. The SPF in vitro was determined by the spectrophotometric method developed by Mansur [22]. Sunscreens can be used as a lotion, gel, spray etc, as a product of topical application which helps in absorbing or reflecting the UV rays to protect a person from sunburn.

ANTIOXIDANT ACTIVITY

Antioxidant activity or capacity of specific compounds means the ability of protecting the system from any potentially harmful process where reactive oxygen (RO) or nitrogen species are produced. Antioxidants have gained great interest [23]. The main function of antioxidants is protecting or defending the entry of ROS into the biological system [24]. Antioxidants present within the algae plays a great role in many diseases and ageing of skin anti-cancer anti-inflammatory etc [8], [24]. Marine algae as they are found in the deep shallow regions are exposed to UV radiation on a large scale in the presence of oxygen. This reaction will lead to the production of ROS. Despite this the algae are not damaged. It depicts a great defence system against the ROS [25]. Algae have been receiving tremendous attention as they have exhibited a potential significance in many industries such as cosmetic, pharmaceutical, used as biopolymer and even as animal feed. Inorganic compounds present in the sun screen are creating threats to both humans and the environment [26]. Mainly titanium dioxide and zinc oxide, even though they act as good UV filters. Oxybenzone and octinoxate are found in about 3 quarters of sunscreen. Recently Hawaii had banned sunscreen which contains these 2 chemicals [27]. Recently studies were done on the oxybenzone and how it affects endocrinology effects in fishes and rats [28], and effect the thyroid and reproductive function [29]. UV filters do also affect the environment adversely. As many wastewater plants in Korea, China, USA, Brazil, Japan, Thailand, and Switzerland are facing a tough situation to remove the chemical UV filters [30]. In vitro studies have shown that oxybenzone has been exhibited in coral reef bleaching, DNA deformation in larval stage, and ossification [31]. 4- methylbenzylidene camphor, a chemical compound used in UV filters, has been detected in many fishes in Switzerland [32]. Through this bioaccumulation they will remain in the food chain and will end up affecting the humans. Therefore usage of organic /natural or replacing the chemical which has an adverse effect on humans and environments with natural products is indeed a great responsibility.

CHEMICAL COMPUNDS PRESENTIN MARINE ALGAE

Composition of active compounds present in the macro algae varies based on the environmental condition and genetic variation. The seaweeds are rich in vitamin B content; certain others are rich in vitamin C, vitamin E and in antioxidant activity [33]. Vitamin composition in seaweed varies depending on algal variety, growth stage, temperature, geological regions, salinity, etc. [34]. Brown algae and red algae both are rich in both vitamin B1 and vitamin B2. And green algae and brown algae are rich in vitamin C [35]. Eicosapentaenoic acid (EPA), a fatty acid which belongs to the PUFA family, is gaining a great interest [36]

STEROLS

Sterol, mainly cholesterol, is considered as the main component in algae. And there is a wide variety of sterols in algae [37].

Table 1: Type of Algae and Sterols [37]

Types of seaweed	Sterol present
Green seaweeds	28 type of ucholesterol, , cholesterol, 24 methylene cholesterol and β -sitosterol
Brown seaweeds	fucosterol, cholesterol and brassicasterol
Red seaweeds	desmosterol, cholesterol, sitosterol, fucosterol and chalinasterol



CAROTENOIDS

Carotenoids are a natural photosynthetic red, yellow and orange wavelength pigment, considered to be abundant in nature. Mainly found in higher plants, photosynthetic bacteria, and all algae. This natural pigment is derived from isoprene, a five carbon unit which is enzymatically polymerized to form 40 carbon structures with 15 conjugated bonds. They have an important role in algae as they are the main constituent of the photosynthetic system. They act as 1) associate pigment in photosynthesis 2) it helps to stabilize protein structure in the photo system 3) it inhibits photo oxidation or free radical oxidation by excess photo exposure[38].

Table 2: Type of Algae and Carotenoids[39]

Type of seaweed	Carotenoids present
Green seaweed	β -carotene, lutein, violaxanthin, neoxanthine and zeaxanthine
Red seaweed	α and β carotene, lutein and zeaxanthin
Brown seaweeds	β -carotene, violaxanthin and fucoxanthin

POLYSACCHARIDE

Seaweeds or marine algae are rich in different types of polysaccharide. Mainly they are found in the cell wall, mycopolysaccharides, storage polysaccharide . Polysaccharides are simple monosaccharide chains (or sugars) which are linked by glycosidic bonds. Mainly green seaweed contain high amount of polysaccharide

DIETARY FIBERS

Seaweeds	Type of polysaccharide present
Chlorophyceae	Sulphated galactan, sulphuric acid polysaccharide
Pheophyceae	Lignin acid, fucoindan or sulphated fucose, laminarian or β -1, 3 glucan
Sargassan and Rhodophyceae	carrageenans, floridean starch, water soluble sulphated galactan, mucopolysaccharide

Table 3: Type of Algae and Dietary Fibbers[40]

Seaweed dietary fibres are very diverse in their composition, chemical structure, and properties. The fibre content is about 33%-62% which is higher when compared to plants[41]. Dietary fibres are classified into two in case of seaweed they are: 1) water insoluble 2) water soluble. Cellulose, mannans and xylans are examples for water insoluble and agars, alginic acid, furonan, laminarin and porphyran are examples for water soluble.

Agar is also a type of polysaccharide it is a mixture of agarose and agro pectin[42]

CARRAGEENAN

It is a generic family name for a water soluble sulphated galactans .This carrageenan are mainly used in ice creams ,puddings, jellies, jams etc they act as emulsifiers and stabilizers. They also have an importance as they are used potential as anti-tumour, anti-viral, anti-coagulant and immunomodulation activity [43]. There are 5 types of carrageenan: λ -carrageenan, ι -carrageenan, κ -carrageenan, μ -carrageenan, and ν -carrageenan.

ALGINATE

Alginate is a linear type of polysaccharide which is a 1, 4 linkage of β -D-mannuronic and α -L-guluronic acid . Alginate is used in pharmaceutical, textile, and food industries. Alginates are present in two acids and salt form [42].

PHYCOCOLLOIDS

Phycocolloids, a high molecular weight polysaccharide, are one of cell wall structural components. Phycocolloids are the one which help to detect pathogens in seaweeds[44]. Phycocolloids are of three groups 1) alginates, 2) agar and 3) carrageenan, these are mainly used in both food industry and cosmetic[45].

SUNPROTECTION FACTOR AND ITS IMPORTANCE

Skin is the largest organ and it has an important function in defending. Main cells in the skin layer are keratinocytes and melanocytes. Both cells have a great role such as keratinocytes help to repair cells which occurred during any skin damage. And melanocytes provide UV protection and determine skin colour [46]. Recently the consumers are unsure about the chemical ingredients used in the composition. Naturally and environmentally friendly products are becoming extremely prominent. Application of algae based has garnered considerable attention over recent years in medicine, cosmetics, horticulture, food etc. There are around 220 commercially valuable seaweeds and nearly 10 species were highly cultivated such as *Saccharina japonica*, *Undaria pinnatifida*, and *Sargassum fusiforme* which belong to brown algae family, *Porphyra spp.*, *Eucheuma spp* *Kappaphycus alvarezii*, and *Gracilaria spp*- red seaweed family, *Ulva clathrata*, *Enteromorpha clathrata*, *Monostroma nitidum*, and *Caulerpa spp*- green seaweed family. Skin ageing is a complex slow process and they are of two types: intrinsic and extrinsic ageing. Ageing of skin includes dryness, pore formation, laxity, wrinkles and fine lining etc. Extrinsic aging results from UV radiation followed by degradation of dermal extracellular matrix, and keratinocyte dysplasia in the epidermis. Marine algae have recently gained attention as it has natural tyrosine inhibitor agents [47]. Polysaccharides have a great role in cosmetics as they are in hair conditioner, moisturizers, emollient etc [48]. Presence of antioxidants helps in reduction of wrinkles, inflammation, tightening of skin etc. Retinoic acid, a type of vitamin A, has been found in cyanobacteria blooms . Algae like *Spirulina maxima* and *Chlorella vulgaris* contain vitamins which in reducing dark circles, treat dandruff etc [49]. Algae is used as a thickening agent in many lotions to maintain its consistency. Agar present in the algae will replace polyethylene glycol and vegetable gum. *Gracilaria*, *Gelidium*. *Chondrus crispus* contains agar, especially carrageenan derived from *Chondrus crispus* which acts as both thickening and stabilizing agent. Mycosporine like amino acids (MAA) are hydrophilic and are one the most important marine natural products. These MAA's protect from UV-A radiation which cause skin damage ultimately can lead to skin cancer. Extract obtained from *Porphyra umbilicalis* (red seaweed) have shown potential UVA protection [50]. Asian scientists have researched on seaweed's health benefits[51]. Researchers are giving significance to marine microalgae and macroalgae to consider it as a healthy beverage and as a meat product [52]. Researchers have exhibited that the extract from brown algae decreased UV-B induced tumour (skin) . Microalgae are getting more important attention and they have been used in producing biofuels, wastewater treatment [53].

Algae is considered a natural photo protective agent due to their unique bioactive substances which have been acquired as an adaptation to the extreme environment combined with a range of physical parameters. These photo protective substances include mycosporine-like amino acids (MAAs), sulphated polysaccharides, carotenoids, and polyphenols [54]. Algal photo protective substances exhibit a wide range of biological activities such as ultraviolet (UV) absorbing, antioxidant, matrix-metalloproteinase inhibitors and immunomodulatory activities. Hence, such unique bioactive substances derived from marine algae have been regarded as having potential for use in skincare, cosmetics, and pharmaceutical products. These bioactive substances found in algae outline their photo protective potential, and provide an overview of developments of blue biotechnology to obtain photo protective substances and their prospective applications [8]. Natural sunscreen compounds such as mycosporine-like amino acids (MAAs) are found in a variety of microbes, most notably in marine algae and cyanobacteria. MAAs is tiny compounds produced from amino acids that are thermally stable and absorb UV light, protecting microbial DNA from radiation damage. Furthermore, algae are far more photo stable than oxybenzene, a common sunscreen ingredient in commercial formulations. They do not react chemically and emit radiation in the form of heat. Most crucially, the sun protection factor (SPF) increased by a factor of more than two when tested in genuine formulations. As a result, they could be good candidates for more stable and effective sunscreen creams[50].

ALGAE AND ITS APPLICATION IN COSMETICS: RECENT STUDIES

Skin is the largest organ and it has an important function in defending. Main cells in the skin layer are keratinocytes and melanocytes. Both cells have a great role such as keratinocytes helps to repair cells which occurred during any skin damage. And melanocytes provide UV protection and determine skin colour[46]. Recently the consumers are unsure about the chemical ingredients used in the composition. Naturally and environmentally friendly products are becoming extremely prominent. Application of algae based has garnered considerable attention over recent years in medicine, cosmetics, horticulture, food etc. There are around 220 commercially valuable seaweeds and nearly 10 species were highly cultivated such as *Saccharina japonica*, *Undaria pinnatifida*, and *Sargassum fusiforme* which belong to brown algae family, *Porphyra spp.*, *Eucheuma spp.*, *Kappaphycus alvarezii*, and *Gracilaria spp.* red seaweed family, *Ulva clathrata*, *Enteromorpha clathrata*, *Monostroma nitidum*, and *Caulerpa spp.* green seaweed family.

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Marine algae have been used in many food industries and cosmetics , for example phycocyanin as it is used as both food additive and colouring agent in both food industry and cosmetic . Astaxanthin, a type of carotenoid, has an important role in scavenging free radical which makes a better one for antioxidants. Agar, one of main products from algae, especially *Gracilaria species* produce high amounts of agar and this species have been famous for their thickening, gelling and stabilizing character. Brown algae are rich in phlorotannin which have exhibited anti ageing, anti melanogenic, anti inflammation, and antioxidant activity [57]. Fucoidan and fucoxanthin, a type of polysaccharide and carotenoids both are anti melanogenic , antioxidant ,anti- cancer in nature[58]. In a recent study, it was an *in vitro* study on dermal fibroblast cells using *Corallina pilulifera* methanol extract and it exhibited the ability to reduce stress induced by UV and gelatinase expression. *Macrocystis pyrifera*, *Turbinaria conoides* are the type of brown algae which have both antioxidant, anti skin ageing character.

II. CONCLUSION

Algae are the abundant source of structurally diverse and functionally active metabolites and they have drawn great attention for the industries of health and cosmetics. Main reason for the attention is due to the pigments, and bioactive components such as MAA's, polysaccharides, carrageenan etc. They have great function and application in many industries. Algal extracts are proven to enhance skin health by reducing skin ageing, wrinkling, increasing skin whitening, and also boost collagen.

Increasing consciousness about the hazard chemicals lead to the emergence of natural products. This review will give insight about the important compounds and can consider algae as an promising and profitable raw material for many sector of industries.

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REFERENCES

- [1] H. N. Toxic effects of ultraviolet radiation on the skin. Toxicology and applied pharmacology, 195(3), 298-308.
- [2] Pangestuti, R., Siahaan, E. A., & Kim, S. K. (2018). Photoprotective substances derived from marine algae. Marine drugs, 16(11), 399 2004.
- [3] Latha, M. S., Martis, J., Shobha, V., Shinde, R. S., Banger, S., Krishnankutty, B., ... & Kumar, B. N. (Sunscreening agents: a review. The Journal of clinical and aesthetic dermatology, 6(1), 16 2013.
- [4] Hoek, C., Mann, D., Jahns, H. M., & Jahns, M.. Algae: an introduction to phycology. Cambridge university press 1995.
- [5] Croft, M. T., Warren, M. J., & Smith, A. G. . Algae need their vitamins. Eukaryotic cell, 5(8), 1175-1183 2006.
- [6] Round, F. E. The ecology of algae. CUP Archive 1984.
- [7] (Hassan, Z., Khan, M. K., Saeed, F., Hassan, S., & Suleria, H. A. R. Therapeutic Potential of Marine Foods: A Review. Health Benefits of Secondary Phytocompounds from Plant and Marine Sources, 137-168 2021.
- [8] (Zubia, M., Fabre, M. S., Kerjean, V., & Deslandes, E. Antioxidant and cytotoxic activities of some red algae (Rhodophyta) from Brittany coasts (France) 2009.
- [9] (Sevrin-Reyssac, J., & Pletikoscic, M. . Cyanobacteria in fish ponds. Aquaculture, 88(1), 1-20 1990.
- [10] Keeling, P. J. The endosymbiotic origin, diversification and fate of plastids. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1541), 729-748 2010.
- [11] Cole, K. M., & Sheath, R. G. (Eds.). Biology of the red algae. Cambridge University Press 1990.
- [12] ("Phylogeny and molecular evolution of green algae." PhD diss., Universiteit Gent, 2009.
- [13] Beetul, K., Gopechund, A., Kaulysing, D., Mattan-Moorgawa, S., Puchoo, D., & Bhagooli, R. . Challenges and opportunities in the present era of marine algal applications. Algae-Organisms for Imminent Biotechnology; Thajuddin, N., Dhanasekaran, D.,(2016

- [14] Vale, M. A., Ferreira, A., Pires, J. C., & Gonçalves, A. L. CO₂ capture using microalgae. In *Advances in Carbon Capture* (pp. 381-405). Woodhead Publishing 2020.
- [15] Abalde, J., Cid, A., Fidalgo Paredes, P., Torres, E., & Herrero, C. *Microalgas: cultivo y aplicaciones* 1995.
- [16] Sheehan, J., Dunahay, T., Benemann, J., & Roessler, P. A look back at the US Department of Energy's aquatic species program: biodiesel from algae. *National Renewable Energy Laboratory*, 328, 1-294 1998.
- [17] Peng, L., Fu, D., Chu, H., Wang, Z., & Qi, H. Biofuel production from microalgae: a review. *Environmental Chemistry Letters*, 18(2), 285-297, 2020.
- [18] Lundquist, T. J., Woertz, I. C., Quinn, N. W. T., & Benemann, J. R. A realistic technology and engineering assessment of algae biofuel production. *Energy Biosciences Institute*, (2010).
- [19] Laraib, N., Hussain, A., Javid, A., Hafeez-ur-Rehman, M., Bukhari, S. M., Rashid, M., & Ali, W. Recent advancements in microalgal-induced remediation of wastewaters. In *Microorganisms for sustainable environment and health* (pp. 205-217). Elsevier. 2020
- [20] Sarkany, R. Sun protection strategies. *Medicine*, 45(7), 444-447 2017.
- [21] Schalka, S., & Reis, V. M. S. D. . Sun protection factor: meaning and controversies. *Anais brasileiros de dermatologia*, 86, 507-515 2011.
- [22] R. M.. Determination of sun protection factor (SPF) of sunscreens by ultraviolet spectrophotometry. *Revista Brasileira de Ciências Farmacêuticas*, 40(3), 381-385 2004.
- [23] Karadag, A., Ozcelik, B., & Saner, S.). Review of methods to determine antioxidant capacities. *Food analytical methods*, 2(1), 41-60 .2009.
- [24] J. . Antioxidants from macroalgae: potential applications in human health and nutrition. *Algae*, 25(4), 155-171 2010.
- [25] Mallick, N., & Mohn, F. H. . Reactive oxygen species: response of algal cells. *Journal of Plant Physiology*, 157(2), 183-193, 2000.
- [26] Li, H., Colantonio, S., Dawson, A., Lin, X., & Beecker, J.. Sunscreen application, safety, and sun protection: the evidence. *Journal of cutaneous medicine and surgery*, 23(4), 357-369 2019.
- [27] Narla, S., & Lim, H. W. . Sunscreen: FDA regulation, and environmental and health impact. *Photochemical & Photobiological Sciences*, 19(1), 66-70 2020.
- [28] Ma, R., Cotton, B., Lichtensteiger, W., & Schlumpf, M. . UV filters with antagonistic action at androgen receptors in the MDA-kb2 cell transcriptional-activation assay. *Toxicological Sciences*, 74(1), 43-50 2003
- [29] Yeager, D. G., & Lim, H. W. . What's new in photoprotection: a review of new concepts and controversies. *Dermatologic clinics*, 37(2), 149-157. 2019.
- [30] Schneider, S. L., & Lim, H. W. . Review of environmental effects of oxybenzone and other sunscreen active ingredients. *Journal of the American Academy of Dermatology*, 80(1), 266-271 .2019.
- [31] Downs, C. A., Kramarsky-Winter, E., Segal, R., Fauth, J., Knutson, S., Bronstein, O., ... & Loya, Y. Toxicopathological effects of the sunscreen UV filter, oxybenzone (benzophenone-3), on coral planulae and cultured primary cells and its environment. 2016.
- [32] Balmer, M. E., Buser, H. R., Müller, M. D., & Poiger, T. Occurrence of some organic UV filters in wastewater, in surface waters, and in fish from Swiss lakes. *Environmental science & technology*, 39(4), 953-962. 2005
- [33] Škrovánková, S. Seaweed vitamins as nutraceuticals. *Advances in food and nutrition research*, 64, 357-369. 2011
- [34] Norziah, M. H., & Ching, C. Y. . Nutritional composition of edible seaweed *Gracilaria changgi*. *Food chemistry*, 68(1), 69-76 2000.
- [35] McDermid, K. J., & Stuercke, B. . Nutritional composition of edible Hawaiian seaweeds. *Journal of Applied Phycology*, 15(6), 513-524 2003.
- [36] Núñez-Pons, L., Avila, C., Romano, G., Verde, C., & Giordano, D. . UV-protective compounds in marine organisms from the Southern Ocean. *Marine drugs*, 16(9), 336 2018.
- [37] Sánchez-Machado, D. I., López-Cervantes, J., Lopez-Hernandez, J., & Paseiro-Losada, P. . Fatty acids, total lipid, protein and ash contents of processed edible seaweeds. *Food chemistry*, 85(3), 439-444 .2004.
- [38] Zhang, Z., Wang, F., Wang, X., Liu, X., Hou, Y., & Zhang, Q. . Extraction of the polysaccharides from five algae and their potential antioxidant activity in vitro. *Carbohydrate Polymers*, 82(1), 118-121 2010.
- [39] Takaichi, S. Tetraterpenes: carotenoids. *Natural Products*; Ramawat, KG, Mérillon, J.-M., Eds, 3251-3283 2013.
- [40] Marinho, G. S., Sørensen, A. D. M., Safafar, H., Pedersen, A. H., & Holdt, S. L. Antioxidant content and activity of the seaweed *Saccharina latissima*: A seasonal perspective. *Journal of Applied Phycology*, 31(2), 1343-1354 2019.
- [41] Lahaye, M., & Kaeffer, B. (1997). Seaweed dietary fibres: structure, physico-chemical and biological properties relevant to intestinal physiology. *Sciences des Aliments (France)*.
- [42] Rasmussen, R. S., & Morrissey, M. T. . Marine biotechnology for production of food ingredients. *Advances in food and nutrition research*, 52, 237-292 2007.



- [43] Carlucci, M. J., Pujol, C. A., Ciancia, M., Nosedá, M. D., Matulewicz, M. C., Damonte, E. B., & Cerezo, A. S. Antiherpetic and anticoagulant properties of carrageenans from the red seaweed *Gigartina skottsbergii* and their cyclized derivatives, 1997.
- [44] Bouarab, K., Potin, P., Correa, J., & Kloareg, B. Sulfated oligosaccharides mediate the interaction between a marine red alga and its green algal pathogenic endophyte. *The Plant Cell*, 11(9), 1635-1650 1999.
- [45] Mayer, A. M., & Lehmann, V. K. Marine pharmacology in 1999: antitumor and cytotoxic compounds. *Anticancer Research*, 21(4), 2489 2001.
- [46] Brenner, M., & Hearing, V. J. The protective role of melanin against UV damage in human skin. *Photochemistry and photobiology*, 84(3), 539-549 2008.
- [47] Thomas, N. V., & Kim, S. K. Beneficial effects of marine algal compounds in cosmeceuticals. *Marine drugs*, 11(1), 146-164 2013.
- [48] Goddard, E. D., & Gruber, J. V. (Eds.). Principles of polymer science and technology in cosmetics and personal care. CRC press 1999.
- [49] Kalasariya, H. S., Dave, M. P., Yadav, V. K., & Patel, N. B. Beneficial effects of marine algae in skin moisturization and photoprotection. *Int. J. Pharm. Sci. Health CARE*, 5, 1-11. 2020
- [50] Shick, J. M., & Dunlap, W. C. MYCOSPORINE-LIKE AMINO ACIDS AND RELATED. *Annu. Rev. Physiol*, 64, 223-62 .2002.
- [51] Rupérez, P. Mineral content of edible marine seaweeds. *Food chemistry*, 79(1), 23-26 2002.
- [52] Cornish, M. L., & Garbary, D. J. Antioxidants from macroalgae: potential applications in human health and nutrition. *Algae*, 25(4), 155-171 2010.
- [53] Venkata Subhash, G., Chugh, N., Iyer, S., Waghmare, A., Musale, A. S., Nandru, R., ... & Dasgupta, S. (2020). Application of in vitro protein solubility for selection of microalgae biomass as protein ingredient in animal and aquafeed. *Journal of Applied Phycology* 2020.
- [54] Hassan, Z., Khan, M. K., Saeed, F., Hassan, S., & Suleria, H. A. R. Therapeutic Potential of Marine Foods: A Review. *Health Benefits of Secondary Phytochemicals from Plant and Marine Sources*, 137-168 2021.
- [55] Rupérez, P. Mineral content of edible marine seaweeds. *Food chemistry*, 79(1), 23-26 2002.
- [56] Cornish, M. L., & Garbary, D. J. Antioxidants from macroalgae: potential applications in human health and nutrition. *Algae*, 25(4), 155-171 2010.
- [57] Yoon, N. Y., Eom, T. K., Kim, M. M., & Kim, S. K. Inhibitory effect of phlorotannins isolated from *Ecklonia cava* on mushroom tyrosinase activity and melanin formation in mouse B16F10 melanoma cells. *Journal of agricultural and food chemistry*, 2009.
- [58] Urikura, I., Sugawara, T., & Hirata, T. Protective effect of fucoxanthin against UVB-induced skin photoaging in hairless mice. *Bioscience, biotechnology, and biochemistry*, 75(4), 757-760 2011



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