



Role of marine macroalgae in Skin hydration and photoprotection benefits: A review

Nikunj B Patel¹, Varsha Tailor², Mohsin Rabadi³, Dr. Ankita Jain⁴, Haresh Kalasariya^{5*}

^{1,3} Smt. S. S. Patel Nootan Science & Commerce College, Sankalchand Patel University, Visnagar, Gujarat, India

^{2,4} BhagwanMahavir College of Science and Technology, Bhagwan Mahavir University, Surat, Gujarat, India

Abstract

Macroalgae, similarly known as macroscopic marine algae, benthic, photosynthetic, nonflowering plants belong to Kingdom Plantae. They are commonly found attached with rocks, sand particles, pebbles, shells, in shallow water, or other anchoring with aquatic plants. Macroalgae are rich in bioactive constituents such as carbohydrates, proteins, lipids, fatty acids, amino acids, vitamins, minerals, pigments, etc. These phyco compounds have great attention for many biological activities which can be beneficial in skin cosmetics. Many researchers reported useful activities of these phyco compounds in the protection of the skin against UV induced damaging effects and skin dehydration. Macroalgae possess photoprotective substances to include mycosporine-like amino acids (MAAs), sulfated polysaccharides, carotenoids, and polyphenols. These compounds also show UV absorbing activity as well as antioxidant activity. Other research reported role of seaweed such carbohydrates, fatty acids, lipids as well as sulfated polysaccharides in skin moisturizing activity. Hence, such unique seaweed-derived bioactive compounds have been regarded as having potential for use in skincare, cosmetics, and pharmaceutical products. The present review study aims to check the applicability of marine macroalgae in skin cosmeceutical activities such as skin moisturization and photoprotection.

Keywords: macroalgae, photoprotection, skin moisturization, cosmeceuticals, seaweeds

Introduction

Marine macroalgae, similarly known as seaweed which is a macroscopic, benthic, and non-flowering plant. It is commonly found on attached with rocks, dead corals, pebbles, shells, grooves of rocks, or by anchoring with sand particles [1]. It is commonly divided into three different types based on the presence of its photosynthetic pigments such as green algae (Chlorophyta), brown algae (Phaeophyta) and red algae (Rhodophyta) [2]. It possesses a wide variety of pigments in it such as former phylum contains chlorophyll a, chlorophyll b, carotenoids, xanthophyll whereas brown algae possess Phaeophyceae, xanthophyll, carotenoids, etc. And the last phylum showed erythrophycin, phycocyanin, phycoerythrin, chlorophyll a and b, carotenoids, etc [3]. Indian coastal line is about 7500 km with diversified habitat and rich biota. The total 271 genera and 1153 species of marine algae, including different types and varieties have been reported from the Indian waters [4]. Another study showed about 184 species of green, 166 species of brown, and 420 species of red seaweeds have been reported from different parts of the Indian coastal line [5]. In India, several species of macroalgae with luxuriant growth occur along the southeast coast of Tamilnadu. It was found from Rameshwaram to Kanyakumari covering 21 Islands in the Gulf of Mannar. However, the cultivation of seaweed carried out at the highest level on the coast of Tamilnadu [6]. The pattern of ecology, distribution, and seasonal succession of the littoral algae of the Indian coast studied by Krishnamurthy V and HV Joshi (1970) with a checklist containing 525 species and 830 species of marine algae along in Indian coast reported by Untawale *et al.* (1983), Oza RM and Zaidi SH (2001) [7, 8, 9]. Srinivasan (1960) reported Gujarat has the longest coastline about 1600 km consisting of the Gulf of Kutch and Gulf of

Khambhat with a rich diversity of seaweeds [10]. These two gulf regions have diversified coastal habitat as well as ecological significance. The former one region is the biggest gulf on the west coast of India in the Arabian sea and contains 42 islands with the high tidal amplitude of the Saurashtra coast [11]. There are many sites where marine macroalgae found such as Okha to Dwarka and Vumani, Adhtra, Saurashtra Diu, Gopnath, Porbandar, and Veraval sites [12]. Different species of seaweed belonging to Rhodophyta, Phaeophyta, and Chlorophyta recorded by H Kalasariya *et al.* (2020) [13]. Many researchers evaluated and characterized different species of macroalgae such as fatty acid analysis, amino acid analysis, polysaccharide, and fatty acid analysis, phenolic compounds, and Pigments content, etc [14]. These types of characterization helpful to know its active biological constituents and lead to predicting its biological activities [15]. It can be applied in various industrial applications such as pharmaceuticals, cosmeceuticals, food and dairy industry, textile industry, as well as the chemical industry [16]. These seaweeds are also utilized in different uses such as bioremediation, medicines, fertilizers, biofuels, cosmetics, food ingredients, etc [17]. Due to over expanding the market of cosmeceuticals, cosmetic industries are formulating cosmetic products by using synthetic chemicals or harmful toxic constituents. These harmful toxic chemicals accumulate in skin layers and create toxicity. It may cause dryness of the skin, blotch, harmful rashes, dark patches and spots, browning of the skin, skin cancer as well as itching with side symptoms nausea, allergies, eye burns, headache, vomiting, etc [18]. Instead of harmful sides of application, people are more attentive to deal with an alternative ingredient that is natural and to reduce the usage of toxic chemicals. Many alternative natural sources such as herbal, plant extracts, marine

resources such as animal products, seaweed, aquatic plants, etc. The marine ecosystem is a rich source of renewable resources and an abundant source of bioactive substances with both pharmaceutical and cosmetic properties. For many years, seaweeds have become a key ingredient in cosmetic products such as soaps, lotion, shampoos, moisturizers, powders, creams, lipsticks, and sprays, etc [19]. Use of seaweed in the cosmetic industry in bioactive ingredient to reduce toxic chemicals. Among them, a wide applicability of seaweeds in skin cosmetic benefits such as skin whitening effects skin hydration, in photoprotection, skin aging, wound healing effect, antimicrobial effects, skin wrinkle activity, anticellulite activity, etc [20]. This noted skin beneficiary applications due to the presence of such bioactive phyco-compounds. Phyco-compounds have potential effects on enzyme tyrosinase inhibition, inhibition of Matrix Metalloprotein Complex (MMP), radical scavenging activity, reduce UV induced damage, light absorption, Anti-collagenase, and anti-elastase activity, etc [21]. These compounds are incorporate into cosmetics to optimize their properties; their capacity to stabilize and preserve products and expressed its activities [22].

This present study aims to check the effect of marine macroalgae in skin cosmetic beneficial activities such as skin moisturization and photoprotection. This activity is helpful to predict the usefulness of seaweeds in skin hydration as well as protect skin from photodamaging effects.

Applications of Seaweed in Cosmetics

In vitro studies also demonstrated that the phenolic compounds are UV protective, or have an inhibitory effect on melanogenesis [23]. Carrageenan and alginate are derived from seaweeds used in the cosmetic industry. *Fucus vesiculosus* extract contains algarol, which is used in the fragrance products [24]. A seaweed Carotenoid called astaxanthin being used in anti-aging products. Milled seaweeds are packed and sold as bathwater additives along with essential oils. They are also commercially sold with bath salts [25].

Review study on photoprotection activity

When the skin is exposed to UV radiation, UV rays penetrate dermis and epidermis and induce the production of ROS which causes damage to DNA. This results in hyperpigmentation, premature aging, sunburn, skin cancer, etc [26]. Hence, seaweeds serve as an excellent source for cosmetic products. Marine algal photoprotective substances exhibit a wide selection of biological activities like UV absorbing, antioxidants, matrix-metalloproteinase, anti-aging, and immune-modulatory activities [27]. Sunlight UV radiation is still the most common cause of skin cancer pathogenesis [28]. The photoprotective preparation from seaweeds proved to be safer and more effective. It filters UV radiation that helps to prevent several types of skin damages like sunburn, photo-aging, photodermatoses, or even skin cancer [29]. Bioactive components able to absorb UV radiation can protect human fibroblast cells from UV-induced damage and suppress photoaging in human skin [30]. Macroalgae have developed mechanisms to prevent damage from UVB and UVA radiations, either by producing screen pigments, like carotenoids or by phenolics. The macroalgae are exposed to extreme conditions such as UV radiation and it produces the ROS. Secondary metabolites from seaweeds

play its role as an antioxidant that helps to combat those ROS. These antioxidant substances included pigments like fucoxanthin, carotenoids, mycosporine-like amino acids (MAA), and phenols such as phlorotannins and scytonemins [31]. These bioactive components are capable of absorbing the UV radiation and keep the human fibroblast cells from UV-induced aging. These secondary metabolites that act as UV filters/sunscreen with antioxidant activity can be extensively used in cosmetic products [32, 33]. studied the photoprotection ability of fucoxanthin on UV induced human fibroblast cells and showed to significantly inhibit the cell damage at 61.24% at 250 μ M due to the presence of conjugated polyene and terminal ring moieties of astaxanthin help to trap the radicals and therefore exhibit potent antioxidative and photo-protective agents. Tetraprenyltoluquinolchromanemeroterpenoid extracted from *Sargassum muticum* (Yendo) Fensholt showed potent photoprotection against UV-A radiation and also inhibit the accumulation of intracellular ROS in human dermal fibroblast cells [34]. Phlorotannins extracted from *E. cava* and *E. stolonifera* also provided photoprotection towards UVB rays by reducing the cell damage caused by UVB radiation which is measured by comet assay. It also showed the inhibition against UVB induced oxidative damage with antioxidant activities and also upgrading in cell viability [35]. Phlorotannins extracted from *Halidryssiliquosa* (Linnaeus) Lyngbye proved the sunscreen ability based on the sun protection factor and UV-A protection factor. It also was shown to exhibit strong antioxidant activity and proved to have the ability to kill bacteria [36]. The aqueous extracts of *Hydropuntia cornea* (J. Agardh) M.J. Wynne and *Gracilariopsis longissima* (S.G. Gmelin) Steentoft, L.M. Irvine & Farnham exhibited a photo-protective activity with the sun protection factor of 7.5 and 4.8. The MAA MAA can also absorb UV light and also act as a sunscreen [37, 38]. It also acts as a better UV filter compared to synthetic sunscreens [39, 40]. The applicability of different macroalgae in photoprotection activities tabulated in table no.1.

Applicability of seaweed for skin moisturization

Skin moisturizer is a formulation that is made up of a complex mixture of harmless natural ingredients that hydrates the skin and layers. Acne aggravation, eczema, physical texture as well as smoothness of skin arise if the skin is not properly moisturized [41]. Moisturizing and hydration are crucial for skincare and are essential to maintain its healthy appearance and elasticity, while also strengthening its role as a barrier to harmful factors [42]. Thereby, moisturizers help in retaining the moisture content of the skin that improves skin dryness, bruising, and wrinkles. Some studies suggested that water along with certain acids such as hyaluronic helps in moisturizing the human skin [43]. Many scientists characterized the profile of polysaccharides and evaluated its beneficiary skin moisturization activities [44]. Polysaccharides such as alginate, agar, carrageenan, and fucoidans from certain algal species help to regulate the distribution of water in the skin [45]. Polysaccharides play a very important role in cosmetic formulations as humectants and moisturizers. According to Wang and colleagues [46], polysaccharides extracted from *Saccharina japonica* revealed better moisturizing properties than hyaluronic acid, suggesting that these polysaccharides could be an interesting ingredient for cosmetics. A cosmetic formulation containing 5–10% extract of *Laminaria*

japonica improved skin moisture [47]. This purpose serves many benefits with non-toxic, economical, abundant algal biomass which can be used as an alternative for harmful preparation containing acetyl alcohol, or silicone-derived ingredients [48]. Many Studies reported 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 regulates water circulation which keeps the skin moisturized in extremely hot and dry environments [49]. The skin hydration activities of different seaweeds expressed in table no.2.

Discussion

Macroalgal derived phycocompounds have been used in skin cosmetic formulations due to their beneficial properties. Due to increasing attention towards an alternative source of ingredients in cosmetic production.

Macroalgae considered a source of value-added compounds, with scientific output showing their usefulness for human health and wellbeing. These aspects be an advantage for many growing industrial applications such as in pharmaceuticals, cosmetic industry, food and dairy, polymer industry, etc. Among them, seaweeds have many biological effects such as skin whitening effect by melanin inhibition, antiaging, antioxidant, moisturizing, collagen-boosting, antiwrinkle, photoprotection to relieve UV induced damage, anti-inflammatory, anti-cellulite and slimming, antimicrobial activity such as antiviral, antibacterial, antifungal, etc. This review has summarized some of the possible applications of macroalgae as active ingredients in photoprotection as well as skin hydration which is an alternative for synthetic cosmetic products. Also, many other beneficial properties will be put forward by the cosmetic industries for further evaluation.

Table 1: Role of different macroalgae in the protection of the skin against photodamage.

No.	Marine Macroalgae	Activities/Effects	References
1	<i>Catenellarepens</i>	Photoprotection	(50,51)
2	<i>Porphyra sp.</i>	Photoprotection	(52)
3	<i>Dunaliellasalina</i>	Photoprotection	(53)
4	<i>Ulvalactuca</i>	Photoprotection	(53)
5	<i>Tetraselmisuecica</i>	Photoprotection	(54)
6	<i>Porphyratenera</i>	Photoprotection	(55)
7	<i>Ecklonia cava</i>	Photoprotection	(56)
8	<i>Chlorella sorokiniana</i>	Photoprotection	(57)
9	<i>Eucheumacottonii (Kappaphycusalvarezii)</i>	Photoprotection	(57)
10	<i>Eucheumaspinosum (Eucheumadenticulatum)</i>	Photoprotection	(58)

Table 2: Role of different macroalgae in skin moisturization.

No.	Algal Species	Activities/Effects	References
1	GenusWakame	Skin moisturizer	(59)
2	<i>Spirulina sp.</i>	Skin moisturizer	(59)
3	<i>Chlorella sp.</i>	Skin moisturizer	(59)
4	<i>Codiumtomentosum</i>	Moisturizer	(60)
5	<i>Ulvaaustralis (as Ulvapertusa)</i>	Skin moisturizer	(61,62)
6	<i>Ulva. Lactuca</i>	Skin moisturizer	(63,64)
7	<i>C. tomentosum</i>	Skin moisturizer	(65,66)
8	<i>Vertebratalanosa, Polysiphonialanosa</i>	Skin moisturizer	(65,66)
9	<i>Undariapinnatifida</i>	Skin moisturizer	(65,66)
10	<i>ChondrusCrispus</i>	Skin moisturizer	(65,66)
11	<i>Palmari Palmate</i>	Moisturizer	(61,62)
12	<i>Palmariumbilicalis</i>	Moisturizer	(61,62)
13	<i>Rhizocloniumhieroglyphicum</i>	Moisturizer	(67)
14	<i>Laminaria japonica</i>	Skin moisturizer	(68)
15	Irish moss	Moisturizer	(69)
16	<i>Postelsiapalmaeformis</i>	Moisturizer	(70)
17	<i>Laminaria hyperborean</i>	Moisturizer	(71,72)
18	<i>Saccharina japonica</i>	Moisturizer	(65,66)
19	<i>S. japonica</i>	Moisturizer	(65,66)
20	<i>Macrocystis sp.</i>	Moisturizer	(73,74)
21	<i>Chlorella vulgaris</i>	Moisturizer	(75)
22	<i>Cladosiphonokamuranus</i>	Moisturizer	(65,66)
23	<i>Spirulina sp.</i>	Moisturizer	(76)

Acknowledgments

I am very much grateful to the other co-authors for contributing and sharing their knowledge. I am also thankful to the Department of Microbiology, SankalchandPatel University-Visnagar as well as the Department of Biotechnology, BhagwanMahavir University-Surat.

References

1. Haresh Kalasariya, Vasant Patel, Richa Patel, Nikunj Patel, Sunil Rathwa. Seaweeds diversity study of selected BeytDwarka coast in Gujarat, India. 2019; 5(1):141-145.
2. Dhargalkar VK, Geetanjali Deshmukhe. Subtidal marine algae of the Dwarakacoast (Gujarat) Indian Journal of Marine Science, 1996; 25:297-301.

3. Bonanno G, Ornando-Bonaco M. Chemical elements in Mediterranean macroalgae. A review. *Exotoxic. Environ. Saf.* 2018; 148:47-71.
4. Anon. Seaweeds: Wonder Plants of the Sea (ed. Krishnamurthy, V.), Aquaculture Foundation of India, Chennai, 2005, p. 30.
5. Nivedita Sahu. A Critical Survey of Seaweed Diversity of Chilika Lake, India: Indian Institute of Chemical Technology, Algae. 2003; 18(1):1-13.
6. Subba Rao PV, Mantri VA. Indian seaweed resources and sustainable utilization: Scenario at the dawn of a new century. *CurrSci.* 2006; 91(2):164-174.
7. Krishnamurthy V, Joshi HV. A Check-list of Indian Marine Algae. CSMCRI Publication, Bhavnagar, 1970, 36 pp.
8. Untawale AG, Dhargalkar VK, Agadi VV. A list of marine algae from India. Tech. Rep. National Institute of Oceanography, Dona Paula, Goa, India, 1983, 42 pp.
9. Oza RM, Zaidi SH. A revised checklist of Indian marine algae, Bioprospecting of Algae, CSMCRI, Bhavnagar, 2001, Pp 296.
10. Srinivasan KS. Distribution patterns of marine algae in Indian seas. In: Kachiroo P (Ed.), Proceedings of the Symposium on Algology ICAR, New Delhi, Journal of Biotech Research, 1960, pp. 219-242.
11. Desai BN. Seaweed resources and extraction of alginate and agar. In Proceedings of the Seminar on Sea, Salt and Plants, (ed. Krishnamurthy, V.), Bhavnagar, 1967, pp. 343-351.
12. Sreenivasa Rao P, Iyengar EER, Thivy F. Survey of algin bearing seaweed at Adatra reef, Okha. *Curr. Sci.* 1964; 33:464-465.
13. Hareesh Kalasariya, Nikunj B Patel, Lensi N Patel, Khushi D Patel, Maitri V Patel. *World journal of Pharmaceutical Research.* 2020; 9(3):991-1004.
14. Kim Sk, Karadeniz F. Industrial prospects of cosmeceuticals derived from marine mucin. *In Marine cosmeceuticals: Trends and Prospects*; Kim, Sk, Ed; CRC Press:Boca aton. FL, USA, 2012, 391-398.
15. Ali A ElGamal. Biological importance of algae, *Saudi Pharmaceutical Journal*, 2010; 18:1-25.
16. MitaliPriyadarshiniPati, Satyabrata Das Sharma, LakshmanNayak, Chita Ranjan Panda Uses of Seaweed and its Application to Human Welfare: A Review, *International Journal of Pharmacy and Pharmaceutical Sciences*, 2016; 8(10).
17. Karthik B, Vinoth Kumar R. Current Trends in Seaweed Research – Overview *International Journal of Pharmacognosy and Phytochemical Research.* 2019; 11(4):295-298.
18. Liubov Ben-Nun. *Medical Effects of Cosmetics*, Ben-Gurion University of the Negev Faculty of Health Sciences Beer-Sheva, Israel, 2016.
19. Valentina Jesumani, Hong Du 1, Muhammad Aslam, Pengbing Pei, and Nan Huang. Potential Use of Seaweed Bioactive Compounds in Skincare—A Review, 2019.
20. Hareesh Kalasariya, Nikunj B Patel, Varsha Tailor, Richa Patel, Dr. Ankita Jain. *Compliance Engineering Journal*, Role of Marine Macro Algae in Tyrosinase Inhibition: A Review Study, 2020.
21. Rajasulochana P, Preethy V. Glimpses on Cosmetic Applications Using Marine Red Algae, *International Journal of Pharmacy & Technology*, 2015.
22. Pinela J, Prieto MA, Barros L, Carvalho AM, Oliveira MBPP, Saraiva JA, *et al.* Cold extraction of phenolic compounds from watercress by high hydrostatic pressure: Process modeling and optimization. *Sep. Purif. Technol.* 2018; 192:501-512.
23. Agatonovic-Kustrin S, Morton DW. Cosmeceuticals Derived from Bioactive Substances Found in Marine Algae., *Journal of Marine Research and Oceanography*, 2013, 1:106. DOI:10.4172/2332-2632.1000106.
24. Couteau C, Coiffard L. Seaweed Application in Cosmetics. In *Seaweed in Health and Disease Prevention*; Academic Press: Cambridge, MA, USA, 2016.
25. Mc Hugh DJ. A guide to seaweed Industry, FAO Fisheries Technical paper.No.441. Rome, FAO, 2003, Pp 105.
26. Yaushiro Matsumura, Honnavara N. Annanthaswamy (2003) Toxicology effect of ultraviolet radiation on the skin; *Toxicology and Applied pharmacology*, 2004; 195:298-308.
27. Wijesekera I. Development & biological activities of marine-derived bioactive peptides: A review *J. Funct. Foods*, 2010.
28. Lyons NM, O'Brien NM. Modulatory effects of an algal extract containing astaxanthin on UVA-irradiated cells in culture. *J Dermatol. Sci.* 2002; 30:73-84. [CrossRef].
29. Ariede MB, Candido TM, Jacome ALM, Velasco MVR, de Carvalho JCM, Baby AR, *et al.* Cosmetic attributes of algae—A review. *Algal Res.* 2017; 25:483-487.
30. Zappelli C, Barbulova A, Apone F, Colucci G. Effective active ingredients obtained through Biotechnology. *Cosmetics*, 2016, 3:39.
31. Bedoux G, Hardouin K, Burlot AS, Bourgoignon N. Bioactive components from seaweeds: Cosmetic applications and future development. *Adv. Bot. Res.* 2014; 71:345-378.
32. Wang HMD, Li XC, Lee DJ, Chang JS. Potential biomedical applications of marine algae. *Bioresour. Technol.* 2017; 244:1407-1415.
33. Lyons NM, O'Brien NM. Modulatory effects of an algal extract containing astaxanthin on UVA-irradiated cells in culture. *J Dermatol. Sci.* 2002; 30:73-84.
34. Balboa EM, Li YX, Ahn BN, Eom SH, Domínguez H, Jiménez C, *et al.* Photodamage attenuation effect by a tetraprenyltoluquinolchromanemeroterpenoid isolated from *Sargassum muticum.*, *J Photochem. Photobiol. B.* 2015; 148:51-58.
35. Heo SJ, Ko SC, Kang SM, Cha SH, Lee SH. Inhibitory effect of diphenylmethoxyphenol on melanogenesis and its protective effect against UV-B radiation-induced cell damage. *Food Chem. Toxicol.* 2010; 48:1355-1361.
36. Le Lann K, Surget G, Couteau C, Coiffard L, Cérantola S, Gaillard F, *et al.* Sunscreen, antioxidant, and bactericide capacities of phlorotannins from the brown macroalga *Halidryssiliquosa*. *J Appl. Phycol.* 2016; 28:3547-3559.
37. Álvarez-Gómez F, Korbee N, Casas-Arrojo V, Abdala-Díaz RT, Figueroa FL. UV Photoprotection, Cytotoxicity, and Immunology Capacity of Red Algae Extracts. *Molecules*, 2019, 24:341.
38. Oren A, Gunde-Cimerman N. Mycosporines, and mycosporine-like amino acids: UV protectants or

- multipurpose secondary metabolites? FEMS Microbiol. Lett. 2007; 269:1-10.
39. Ryu J, Park SJ, Kim IH, Choi YH, Nam TJ. Protective effect of Porphyra-334 on UVA-induced photoaging in human skin fibroblasts. *Int. J. Mol. Med.* 2014; 34:796-803.
 40. Daniel S, Cornelia S, Fred Z. UV-A sunscreen from red algae for protection against premature skin aging. *Cosmet. Toilet. Manuf. Worldw.* 2004; 129:139-143.
 41. Meha Qassem, Panayiotis Kyriacou. Review of Modern Techniques for the Assessment of Skin Hydration, 2019.
 42. Bedoux G, Hardouin K, Burlot AS, Bourgougnon N. Bioactive components from seaweeds: Cosmetic applications and future development. *Adv. Bot. Res.* 2014; 71:345-378.
 43. Bonté F. "Skin moisturization mechanisms: new data" *Annales Pharmaceutiques Françaises*, 2011; 69:135-41.
 44. Lourdes Mourelle M, ID Carmen P Gómez, José L Legido. The Potential Use of Marine Microalgae and Cyanobacteria in Cosmetics and Thalassotherapy, 2017.
 45. Jae-Suk Choi, WoiSook Moon, Ji Na Choi, Kee Hun Do, Sun Hwa Moon, KwangKeun Cho, *et al.* Effects of seaweed *Laminaria japonica* extracts on skin moisturizing activity in vivo; *Journal of Cosmetic Science.* 2013;0 64:193-205 (May/June 2013).
 46. Wang, J.; Jin, W.; Hou, Y.; Niu, X.; Zhang, H.; Zhang, Q. Chemical composition and moisture-absorption/retention ability of polysaccharides extracted from five algae. *Int. J. Biol. Macromol.* 2013, 57, 26–29.
 47. Choi JS, Moon WS, Choi JN, Do KH, Moon SH, Cho KK, *et al.* Effects of seaweed *Laminaria japonica* extracts on skin moisturizing activity in vivo., *J Cosmet. Sci.* 2013; 64:193-209.
 48. Virendra Kumar Yadav, R Suriyaprabha, Samreen Heena Khan, Bijendra Singh, G Gnanamoorthy, Nisha Choudhary, *et al.* A novel and efficient method for the synthesis of amorphous nanosilica from fly ash tiles, *Materials Today: Proceedings*, 2020. <https://doi.org/10.1016/j.matpr.2020.01.013>., Journal homepage: www.elsevier.com/locate/matpr.
 49. Jean-Baptiste Guillerme, Céline Couteau, and Laurence Coiffard. Applications for Marine Resources in Cosmetics, 2017.
 50. Suh SS, Hwang J, Park M, Seo HH, Kim HS, Lee JH, *et al.* Anti-inflammation activities of mycosporine-like amino acids (MAAs) in response to UV radiation suggest a potential anti-skin aging activity. *Mar Drugs.* 2014; 12:5174-5187.
 51. Gao Q, Garcia-Pichel F. Microbial ultraviolet sunscreens. *Nat Rev Microbiol.* 2011; 9:791-802.
 52. Schubert N, Garcia-Mendoza E, Pacheco-Ruiz I. Carotenoid composition of marine red algae. *J Phycol.* 2006; 42:1208-1216.
 53. Talero E, Garcia-Mauriño S, Avila-Roman J, Rodriguez-Luna A, Alcaide A, Motilva V, *et al.* Bioactive compounds isolated from microalgae in chronic inflammation and cancer. *Mar Drugs.* 2015; 13:6152-6209.
 54. Sansone C, Galasso C, Orefice I, Nuzzo G, Luongo E, Cutignano A, *et al.* "The green microalga *Tetraselmis suecica* reduces oxidative stress and induces repairing mechanisms in human cells." *Scientific Reports*, 2017, 7.
 55. Special Chem—The Universal Selection Source: Cosmetics Ingredients. Available online: <https://cosmetics.specialchem.com/> (accessed on 30 November 2017).
 56. Kim KC, Piao MJ, Zheng J, Yao CW, Cha JW, Kumara MHSR, *et al.* Fucodiphloretol G purified from *Ecklonia cava* suppresses ultraviolet B radiation-induced oxidative stress and cellular damage. *Biomol. Ther.* 2014; 22:301-307.
 57. Chidambara Murthy KN, Vanitha A, Rajesha J, MahadevaSwamy M, Sowmya PR, Ravishankar GA, *et al.* In vivo antioxidant activity of carotenoids from *Dunaliellasalina* – a green microalga. *Life Sci.* 2005; 76:1381-1390.
 58. Thevanayagam H, Mohamed SM, Chu WL. Assessment of UVB-photoprotective and antioxidative activities of carrageenan in keratinocytes. *J Appl. Phycol.* 2014; 26:1813-1821.
 59. Hagino H, Saito M. Use of Algal Proteins in Cosmetics, *Algal Research* 25, 03029218.9, 2010, Pp: 483-487.
 60. Majmudar G. Compositions of Marine Botanicals to Provide Nutrition to Aging and Environmentally Damaged Skin. US Patent 8318178 B2, 2012. Available online: <https://patentimages.storage.googleapis.com/1f/41/48/4dfcee08799f34/US8318178.pdf> (accessed on 22 September 2018)
 61. Borowitzka MA. High-value products from microalgae—Their development and commercialization. *J Appl. Phycol.* 2013; 25:743-756. [CrossRef].
 62. Houston MC. Nutraceuticals, vitamins, antioxidants, and minerals in the prevention and treatment of hypertension. *Prog. Cardiovasc. Dis.* 2005; 47:396-449.
 63. Lahaye M, Robic A. Structure and functional properties of ulvan, a polysaccharide from green seaweeds. *Biomacromolecules.* 2007; 8:1765-1774.
 64. Robic A, Rondeau-Mouro C, Sassi JF, Lerat Y, Lahaye M. Structure and interactions of ulvan in the cell wall of the marine green algae *Ulvarotundata* (Ulvales, Chlorophyceae). *Carbohydr. Polym.* 2009; 77:206-216.
 65. Wang HM, Chou YT, Wen ZH, Wang CZ, Wang CH, Ho ML, *et al.* Novel biodegradable porous scaffold applied to skin regeneration. *PLoS ONE*, 2013, 8:e56330.
 66. Wang J, Jin W, Hou Y, Niu X, Zhang H, Zhang Q, *et al.* Chemical composition and moisture-absorption/retention ability of polysaccharides extracted from five algae. *Int. J Biol. Macromol.* 2013; 57:26-29.
 67. Leelapornpisid P, Mungmai L, Sirithunyalug B, Jiranusornkul S, Peerapornpisal Y. A novel moisturizer extracted from freshwater macroalga [*Rhizoclonium hieroglyphicum* (C. Agardh) Kützing] for skincare cosmetics. *Chiang Mai J Sci.* 2014; 41:1195-1207.
 68. Choi JS, Moon WS, Choi JN, Do KH, Moon SH, Cho KK, *et al.* Effects of seaweed *Laminaria japonica* extracts on skin moisturizing activity in vivo. *J Cosmet. Sci.* 2013; 64:193-209.
 69. "Irish moss". Retrieved by <http://seaboost.ca/products/irish-moss.html> [42]. "Sea Lettuce (*Ulva Lactuca*)". [Date accessed June 28, 2017] Retrieved from <http://www.irishseaweeds.com/sea-lettuce-ulva-lactuca>.

70. "Marine ingredients for anti-aging skincare - truth in aging". [Date accessed June 28, 2017] Retrieved from <https://www.truthinaging.com/review/marine-ingredients-for-anti-aging-skin-care>.
71. Thalgo. La Beaute Marine, 2018. Available online: <http://www.thalgo.com/> (accessed on 22 September 2018).
72. La-Mer My Skin—And What It Needs, 2018. Available online, 2018. <https://www.la-mer.com/en> (accessed on 22 September).
73. Tonnesen HH, Karlsen J. Alginate in drug delivery systems. *Drug. Dev. Ind. Pharm.* 2002; 2:621-630.
74. Mafinowska P. Algae extracts as active cosmetic ingredients. *Zeszy. Naukowe.* 2011; 212:123-129.
75. "Effects of Chlorella extract on skin". *Personal Care Magazine.* [Date accessed June 28, 2017]. Retrieved from <http://www.osmosiskincare.com/research/files/chlorella-extract-on-skin.pdf>.
76. Iraya Serum Body Lotion, Algae, 250ml by Iraya (<https://www.amazon.in/Iraya-Serum-Lotion-Algae250ml/dp/B01IP5N8TG>)
77. "Microalgae fight skin aging". [Date accessed June 28, 2018] Retrieved from [http:// naturalactives.com/microalgae- fights skin-ageing](http://naturalactives.com/microalgae-fights-skin-ageing).