Seaweed-Based Molecules

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Seaweeds are a novel source of potentially active compounds (proteins–lectins, phycobiliproteins, peptides, amino acids, polyphenols, and polysaccharides) to be exploited in human health benefits, such as antiviral, anticancer, anticoagulant, anti-obesity, and diabetes modulator. Shannon and Abu-Ghannam, suggested seaweed as nutraceuticals or functional foods with dietary benefits beyond their fundamental macronutrients, highlighting their significant effect on obesity and dietary related disease. This study also suggested recent developments of seaweed applications for human health from epidemiological and functional food perspectives.

Keywords: cosmeceuticals ; seaweeds ; skin cosmetics ; marine macroalgae ; biological activities

1. Introduction

The chemically diversified nature and unique potential of seaweeds are the reason why they have been the focus of interest for the past few years in various cosmetic applications. Seaweed-based protein, polysaccharides, phenolic compounds, and pigment profiles present cosmetic and cosmeceutical potential. This review study gives an overall view of an exploitation of seaweed for cosmetic beneficial activities. Mainly, the role of polysaccharide, protein, phenolic compounds, and pigments in different skin cosmetic beneficial activities are discussed.

Marine macroalgae produce both primary metabolites, including proteins, amino acids, polysaccharides, fatty acids, etc., and secondary metabolites, such as phenolic compounds, pigments, sterols, vitamins, and other bioactive components [1][2][3][4][5][6][7]. Moreover, various types of biological activities expressed by different phycocompounds, such as blood coagulation system, antilipidemic activity, immunomodulating effect, antiviral activity, anticancer activity, antimicrobial activity, antioxidant activity, and other significant activities [8]. Especially in the area of cosmetics, many scientists reported skin beneficial activities, such as antiaging, anti-wrinkle, anti-cellulite, antioxidant, moisturizing, whitening, and photoprotection [9][10][11][12][13][14][15][16]. Sun and Chavan, [17] studied Fucus vesiculosis extract to reduce the appearance of dark circles on the skin area by enhancing the expression of hemeoxygenase-1. By removing heme catabolites, it eliminates the heme production on skin. Hagino and Saito [18] reported some algae species and derived compounds for UV protection benefits, skin moisturization, and inhibition of melanin synthesis. Leyton et al. [19] identified phlorotannins, pholoroeckol, and phloroglucinol in the extract of brown macroalgae Macrocystis pyrifera . They also reported good antidiabetic and antioxidant activity of phlorotannins, which can prevent skin aging.

There are a wide variety of polysaccharides that are useful in skin cosmetics, such as agar, alginic acid, carrageenan, porphyrin, laminarin, fucoidan, and ulvan. Many genera of agrophytes algae, such as Gelidium sp., Gracilaria sp. , Gelidiela sp. , Pterocladiella sp., etc., are well-known producers of agar-agar [4][20]. Balboa et al. [21] suggested use of agar as a major ingredient in creams, as an emulsifier, stabilizer, moisturizer as well as in different cosmetic products such as lotion, deodorants, antiaging treatment, exfoliant, acne treatment, etc. Like agar, alginic acid is derived from several brown algal species (Fucales, Laminariales, Ascophyllum sp., Durvillaea sp., Ecklonia sp., Laminaria sp., Macrocystis sp., Saccharina sp., Sargassum sp., and Turbinaria sp.) [22][23][24]. Mafinowska [25] and Fabrowska et al. [26] reported its application in the formulation of skin-protective or barrier creams for the treatment of dermatitis, as well as suitable ingredients of beauty masks or facial packs. In addition, Kappa-, Iota-, Lambda-, Beta-carrageenan are extracted from several carrageenophytes, i.e., Betaphycus gelatinum , Chondrus crispus , Eucheuma denticulatum , Gigartina sp., Kappaphycus alvarezii , Hypnea musciformis , Mastocarpus sp., and Mazzaella sp., from the Rhodophyta. It is used in cosmetology for various applications, such as lotion, sun-ray protectors, medicines, deodorant sticks, sprays, and foams [27][28][29][30].

Macroalgae is cultivated in a controlled condition to regulate the production of bioactive compounds such as phenolic compounds, pigments, carbohydrates, proteins, amino acids, vitamins, and minerals [31]. These algae-based valuable bioactive constituents gained attention in cosmeceutical activities [32]. This algae-derived metabolite can repair early signs of skin-aging, has an anti-wrinkle effect, exerts tightening effects, collagen synthesis, etc., as reported from Arthrospira

species (Cyanobacteria) and Chlorella valgaris (Chlorophyta) [33][34]. Marine algae contain a broad range of photosynthetic pigments chlorophylls, carotenoids (carotenes, xanthophylls, fucoxanthin, and peridinin), and phycobilins (phycocyanin and phycoerythrin) [35][36]. As suggested by many researchers, red algae contain chlorophyll, phycobilin, carotenoids, β carotene, lutein, phycocyanin, and phycoerythrin Whereas brown algae possess chlorophyll a, c, carotenoids, fucoxanthin, and other pigments. Likewise, Chlorophyta revealed the presence of chlorophyll-a, -b, and -c and carotenoids [37][38][39][40][41][42][43]. Due to the richness of diversified pigments' profile, it is applied in various applications, such as photoprotection, anti-inflammatory effects, anticancer effects, and the inhibition of cell proliferation [44][45][46][47][48]. The benefits of seaweed-derived pigments are summarized in **Table 1** . According to Takaichi S. [49], Quilodrán et al. [50], and Amon and French [51], algae species are considered as a major source of β-carotene; likewise, some compounds, such as carotenoids, astaxanthin, and docosahexaenoic acid (DHA), show antioxidant activity. Hosikian et al. [52] evaluated the role of green photosynthetic pigments in cosmetic industrial applications for antioxidant and antimutagenic properties. Spears [53] and La-Mer [54] suggested role of chlorophyll as natural coloring agents, deodorizing and antibacterial properties. In addition, these chlorophylls have high antioxidant activity and the ability for tissue-growth stimulation, making them useful to the cosmetic industry [55][56].

Table 1. Skin beneficial activities of marine macroalgae's pigments.

No.	Species	Potential Pigment/s Studied	Cosmetics Properties and/or Products	References
1	***Chaetomorpha antennina*, *Padina gymnospora***	**Chlorophyll, Carotenoid, Xanthophylls, Antioxidant**	**Photoprotection**	[55]
2	***Sargassum aquifolium* (formerly *Sargassum binderi*),**	**Fucoidan**	**Photoprotection**	[56][57]
3	***Ulva lactuca, Caulerpa racemosa*, *Bryopsis plumosa*, *Gelidiella acerosa*, *Hypnea valentiae***	**Chlorophyll Carotenoid**	**Photoprotection**	[58]
4	***Sargassum ilicifolium***	**Fucoxanthin**	**Photoprotection Antioxidant**	[59]
5	***Sargassum polycistum***	**Fucoxanthin β carotene α carotene**	**Antioxidant**	[60]
6	***Haematococcus lacustris* (formerly *Haematococcus pluvialis*)**	**Lutein β carotene**	**Photo-oxidative**	[61]
7	***Sacharina latissima* (formerly *Laminaria saccharina*)**	**Chlorophyll**	**Photo-inhibition**	[62]
8	***Chondrus crispus***	**Carotenoid**	**Photoprotection**	[63]
9	***Kappaphycus alvarezii*, *Padina australis***	**Chlorophyll a β carotene Fucoxanthin Zeaxanthin**	**Photoprotection**	[64]

2. Current Insights

Cosmetic researchers have focused their attention on marine organisms as an additional source of novel and useful natural ingredients. Diversified marine-algae-derived secondary metabolites are structurally more complex, with unique functionalities and properties. This review surveyed the potential applications of marine-algae-derived compounds for various skin benefits in the cosmetic industry. Though many seaweeds are exploited for their cosmetic properties, the research work on them is still incomplete, and so many species, either in full or in part, have not been explored. Hence, the cost-effective and efficient alternative standardized method to extract the bioactive phyco-constituents with significant productivity and activity is in growing demand. In future perspectives, the responsible molecular mechanism and safety concerns of these compounds are very important for future challenges in cosmeceuticals. Therefore, further investigations to study the precise molecular basis for the beneficial activity of marine algal components should be undertaken. Recently,

in silico tools and techniques have been used to select functional materials derived from natural resources quickly and to predict the mechanisms of actions. Thus, this approach will be a helpful strategy for finding and understanding more effective compounds with the novel property.

3. Conclusions

The overexposure of human skin to different environmental stresses, such as pollutants and sun radiation, as well as chemical cosmeceutical ingredients—it increases the production of reactive oxygen species (ROS)—leads to many skin-damaging problems, such as aging, dullness, carcinogenesis, wrinkles, age spots, dark circles, etc. Marine-algae-based bioactive purified compounds demonstrated highly significant beneficiary applications in cosmetic formulas, as multiple functions, where they can be natural active constituents to the synthetic ingredients. Under different environmental factors, marine algae have the biosynthesis of primary and secondary metabolites for their survival. These biologically active constituents can be used as an active ingredient in the cosmetic industries due to their various skin benefits. It could be used as an antioxidant, antimicrobials, antibacterial, whitening agent, antiaging, anti-wrinkle, anti-acne, moisturizing, UV protection, deodorizing, anti-allergic, anti-inflammatory, sensory enhancer, viscosifying, stabilizer, and also for thickening in cosmetic industries. Sustainable use of marine algae and marine-algae-based molecules is crucial for humankind. Moreover, there are many cosmeceutical industries that already use extracts of marine algae and compounds in the formulation of many products. However, the monitoring of its biochemical profile presents a problem that needs to overcome. This can be solved by the development of seaweed cultivation and green extraction methods that are being analyzed with promising research results. However, many cosmetic companies' collaboration at the national and international level can improve the analytical methods of its screening for safety, thus enhancing consumer's safety towards marine-algae-based bioactive compounds in the cosmetic products. All mentioned marine algae in this review, possessing various bioactivities, are considered and utilized as a natural inexhaustible source for different cosmeceutical benefits.

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