

Role of Marine Macroalgae in Cosmeceuticals

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The cosmetic industry uses the term 'cosmeceutical' to refer to a cosmetic formula that has drug-like applicative advantages. Many marine algae are rich in biologically active components that have been reported to exhibit strong benefits to the skin, mainly for photoprotection, skin whitening, moisturization, anti-aging, anti-wrinkle, antioxidants, and antimicrobial uses.

Keywords: seaweeds ; bioactivity ; cosmeceuticals ; skin care ; anti-inflammatory

1. Introduction

In cosmeceuticals, cosmetic products are a topical combination of cosmetic and pharmaceutical with bioactive molecules to have medicinal or drug-like applications to improve health and texture of skin [1][2]. Due to modernization and skin care attention, cosmetic companies are enlarging gradually each year worldwide. To fulfill the requirements of customers, these cosmetic companies are moving towards unbeatable exploitation of synthetic cosmetics and constituents. Due to the ineffectiveness of synthetic components, it may cumulate in skin and produce toxic effects and may cause harm to healthy skin structure. Hydroxybenzoic acid esters (parabens) reported its adverse effect to the skin as well as increase incidence of malignant melanoma and breast cancer since it is widely used in cosmetic formulations [3]. Another substance is phthalate, which is highly found in different cosmetic formulations that can cause DNA mutations and damage, as found in human male gamete [4][5]. Some of these synthetic chemical compounds can cause detrimental effects in animals such as reduction of sperm counts, changed pregnancy outcomes, congenital disabilities of male genitalia, etc. [6]. As a result, users have changed their liking and selected natural cosmetic products for usage [7]. Hence, the enlarging market for skincare formulations and constant look for an alternative natural constituents led to the production of a different types of cosmeceutical skin products [8].

Marine macroalgae (seaweeds) are macroscopic, multicellular, eukaryotic organisms that can perform photosynthesis due to presence of Chlorophyll and some other photosynthetic pigments. They are widely distributed along the coastal line (the intertidal and sub-tidal regions) and in brackish water [9]. Based on pigment composition, they can be classified into three types. Brown alga belongs to Ochrophyta phylum (Phaeophyceae class), red alga belongs to Rhodophyta phylum, and green alga belongs to Chlorophyta phylum. Among these three types, brown algae belong to the Chromista kingdom, whereas green and red algae belong to the Plantae kingdom [9][10]. Seaweeds have a more highly diversified bioactive constituents than terrestrial organisms [11]. These bioactive compounds have a wide range of biological activities which can be used in product preparation as an ingredient [12][13]. The applications of macroalgae in cosmeceutical formulations depends on their constituents (such as polysaccharides, carbohydrate derivatives, proteins, peptides, amino acids, phenolic compounds, vitamins, minerals, fatty acids, pigments, etc.) [14][15]. Many previous findings have reported the role of seaweed based bioactive compounds which offer antitumor, antiallergic, antimicrobial, antioxidant, antiinflammation, antilipidemic activity, antiwrinkle, anti-aging, moisturizing, and photoprotection activities [5][14][16][17][18].

2. Seaweed Derived Metabolites in Cosmetics

For the preparation of cosmeceutical products, macroalgae-derived compounds have been noted as being of significant importance [19]. Polysaccharides have a great role in cosmetics including in moisturizers, emulsifiers, wound healing agents, and thickening agents [20]. Fernando et al. [21] have reported anti-inflammation activity of Fucoidan from *Chnoospora minima* (Phaeophyceae) by inhibition of Lipopolysaccharides induced nitric oxide production, inducible nitric oxide productions, Cyclooxygenase-2, and Prostaglandin E2 levels in an experimental study by targeting RAW macrophages. Likewise, Ariede et al. [22], Wang et al. [23], and Teas and Irhimeh, [24] reported beneficial activities of *Fucus vesiculosus* (**Figure 1a**) (Phaeophyceae) derived polysaccharides such as anti-aging, anti-melanogenic, anti-cancer, and antioxidant activity by stimulating collagen production, tyrosinase inhibition, decreasing melanoma growth and by preventing oxidation formation, respectively. In addition, the anti-inflammation activity of sulphated polysaccharide from

Padina tetrastromatica (Phaeophyceae) by COX-2 and iNOS inhibitions in an experimental model of Paw edema in rats [25]. Moreover, Khan et al. [26] reported the anti-inflammation activity of polyunsaturated fatty acids derived from *Undaria pinnatifida* (Figure 1b) (Phaeophyceae) on mouse ear edema and erythema. In vitro, the antioxidant activity of methanolic extracts from *Osmundaria obtusilo* and *Palisada flagellifera* (Rhodophyta) was studied by DPPH, ABTS, metal chelating, Folin ciocalteau, and beta-carotene bleaching assays [27][28]. Phenolic compound Sargachromanol E revealed antiaging activities from *Sargassum horneri* (Phaeophyceae) by inhibition of matrix metalloprotein expression on UVA irradiated dermal fibroblast [29].



Figure 1. Seaweed species images: (a)—*Fucus vesiculosus* (P); (b)—*Undaria pinnatifida* (P); (c)—*Schizymenia dubyi* (R); (d)—*Ulva linza* (C); (e)—*Bryopsis plumosa* (C); (f)—*Laminaria digitata* (P); (g)—*Palmaria palmata* (R); (h)—*Himanthalia elongata* (P); (i)—*Porphyra umbilicalis* (R); (j)—*Jania rubens* (R); (k)—*Gracilaria gracilis* (R); (l)—*Ceramium virgatum* (R); (m)—*Kappaphycus alvarezii* (R); (n)—*Ulva lactuca* (C); (o)—*Ascophyllum nodosum* (P); (p)—*Eucheuma denticulatum* (R); C—Chlorophyta; R—Rhodophyta; P—Phaeophyceae; Scale = 1 cm.

3. Polysaccharides

Marine macroalgae derived polysaccharides are well known for their biological benefits. The presence of polysaccharides (ulvan, fucoidan, alginate, laminarin, carrageenan, sulphated polysaccharides, agar, and agarose) in macroalgae and noted their cosmeceutical benefits. Other examples of macroalgae derived polysaccharides and their cosmetic benefits are presented in Table 1.

Table 1. Application of macroalgae derived polysaccharides in skin cosmetics.

No.	Name of Macroalgae	Polysaccharides	Cosmetic Benefits	References
1	<i>Ulva lactuca</i> (Figure 1n) (C)	SP (Ulvan)	Antioxidant, Moisturizer, Photoprotective	[30]
	<i>Neopyropia yezoensis</i> (R)	Porphyran	Antiinflammation	[31][32]
2	<i>Porphyridium</i> sp.* (R), <i>Costaria costata</i> (P), <i>Ulva lactuca</i> (Figure 1n) (C)	Sulphated polysaccharides	Antioxidant, Anti-inflammatory, Antiaging	[33]
3	<i>Fucus vesiculosus</i> (Figure 1a)	Fucoidans	Antiaging, Antirinkle	[34]

No.	Name of Macroalgae	Polysaccharides	Cosmetic Benefits	References
4	<i>Ascophyllum nodum</i> (Figure 1o), <i>Chnoospora minima</i> , <i>Sargassum fusiforme</i> , <i>Saccharina japonica</i> , <i>Sargassum polycystum</i> , <i>S. vachellianum</i> , <i>S. hemiphyllum</i> (P)	Fucoidans	Photoprotection, Anti photoaging Anti-inflammatory, Anti-elastase, Anti-collagenase, Skin whitening	[35][36][37][38]
5	<i>Fucus vesiculosus</i> (Figure 1a) (P)	Fucoidan	Anticoagulant Antioxidant, Enhancer of Skin fibroblast formation	[39]
6	<i>Neoporphrya haitanensis</i> (R)	Porphyran	Antioxidant	[40][41]
7	<i>Saccharina longicruris</i> (P)	Laminaran	Anti-inflammation, Antioxidant, Reconstruction of dermis	[42][43]
8	<i>Saccharina longicruris</i> (P)	Galactofucans	Enhance fibroblast formation, Increase synthesis of matrix metalloproteinase (MMP) complex and collagen-1	[44]
9	<i>Eucheuma denticulatum</i> (Figure 1p) (R)	Carrageenan	Antioxidant, photoprotection	[45]
10	<i>Gelidium</i> sp. (R)	Agar	Thickener	[46]
11	<i>Ascophyllum</i> sp., <i>Fucus</i> sp., <i>Sargassum</i> sp., <i>Undaria</i> sp. (P)	Laminaran	Anticellulite	[47]
12	<i>Saccharina cichorioides</i> (P)	Fucoidan	Anti-atopic dermatitis	[48]
13	<i>Corallina officinalis</i> (R)	Sulphated polysaccharides	Antioxidant	[49]
14	<i>Ulva australis</i> (C)	Ulvan	Antiaging	[50][51]
15	<i>Acanthophora muscoides</i> (R)	Sulphated polysaccharides-Carrageenan	Anticoagulant, Antinociceptive, antiinflammation, Gel agents	[52][53][54]
17	<i>Chondrus crispus</i> (R)	Carrageenan	Gel and Thickening agent, Skin moisturizer	[55]
18	<i>Ulva rigida</i> , <i>U. pseudorotundata</i> (C)	Sulphated polysaccharides	Antioxidant, Chelators, Gel agents, Moisturizer	[56]
19	<i>Ascophyllum nodosum</i> (Figure 1o) (P)	Fucoidan	Anti-inflammation, Antiviral, Antiaging, Anti elastase, Photoprotective, Tyrosinase inhibition, Anticellulite	[57]
20	<i>Gracilaria</i> sp. (R)	Agar	Thickener	[58]
21	<i>Padina boergesenii</i> (P)	Sulphated polysaccharides	Formation of collagen	[59]
22	<i>Macrocystis</i> sp., <i>Lessonia</i> sp., <i>Laminaria</i> sp. (P)	Alginate	Gelling and Stabilizing agent, Moisturizer, Chelator	[60][61]
24	<i>Kjellmaniella crassifolia</i>	Fucoidan	Antiaging, Antiwrinkle	[62]
25	<i>Brown algae</i> (P)	Alginate	Thickening agent Gelling agent	[63]
27	<i>Sargassum vachellianum</i> (P)	Polysaccharides	Skin moisturizer and protectors	[64]
28	<i>Fucus vesiculosus</i> (Figure 1a), <i>Laminaria digitata</i> (Figure 1f), <i>Undaria pinnatifida</i> (Figure 1b) (P)	Fucoidan	Antioxidant, Antiaging, Anticoagulant, Increase skin fibroblast formulation	[65][66]
29	<i>Ascophyllum nodosum</i> (Figure 1o) (P)	Fucoidan	Anti-elastase, gelatinase A inhibition, Inhibition of interleukin-1 beta in fibroblast cells	[67]

No.	Name of Macroalgae	Polysaccharides	Cosmetic Benefits	References
30	<i>Ecklonia cava</i> (P)	Phlorotannins	Photoprotectors against UV-B	[68][69]
31	<i>Neoporphrya haitanensis</i> , <i>Gracilaria chouae</i> , <i>G. blodgettii</i> (R)	Agar	Antioxidant, Thickeners Antitumor, Radiation protector, Antiaging	[70][71]
32	<i>Turbinaria conoides</i> (P)	Laminarin, Alginate, Fucoidan	Antioxidant	[72]

SP, Sulphated Polysaccharides; C, Chlorophyta; R, Rhodophyta; P, Phaeophyceae; * Microalgae.

4. Amino Acids

Protein is considered a macromolecule and polymer of amino acids. Pereira [67] reported the role of amino acids as a natural moisturizing factor that prevents water loss in the skin. Marine macroalgae are a satisfactory resource of various amino acids, such as glycine, alanine, valine, leucine, proline, arginine, serine, histidine, tyrosine, and some other mycosporine amino acids (MAAs). Marine macroalgae derived peptides and amino acids and its skin cosmetic benefits are illustrated in **Table 2**. In cosmeceutical products, amino acids usually function as a hydrating agent as a natural moisturizing factor in human skin [73].

Table 2. Applications of macroalgae derived peptides and amino acids in skin cosmetics.

No.	Name of Macroalgae	Compounds	Cosmetic Benefits	References
1	<i>Scytosiphon lomentaria</i> (P)	Amino acids	Antioxidant, Radical scavengers, Chelators	[74][75][76]
2	<i>Gracilaria vermiculophylla</i> (R)	Porphyra-334, Palythine, Asterina-330, Shinorine	Antioxidant, UV protector	[77]
3	<i>Ulva lactuca</i> (Figure 1n) (C), <i>Asparagopsis armata</i> (R)	MAAs, Amino acids	Antiaging, Anti wrinkles, Improves collagen formation	[78]
4	<i>Pelvetia canaliculata</i> (P)	Amino acids	Antioxidant, Collagen formation, Proteoglycan's synthesis	[79]
5	<i>Gracilaria chilensis</i> , <i>Pyropia plicata</i> , <i>Champia novae-zelandiae</i> (R)	MAAs	Anti UV, Antioxidant	[80]
6	<i>Ulva lactuca</i> (Figure 1n) (C)	Arginine, Aspartic acid, Glycine	Enhance collagen and elastin synthesis	[80]
7	<i>Porphyra umbilicalis</i> (Figure 1i) (R)	MAAs, (2:1 ratio of Porphyra-334 and Shinorine)	Antiaging	[81]
8	<i>Palmaria palmata</i> (Figure 1g), <i>Catenella caespitosa</i> (R)	MAAs	UV and UV-A protection	[82]
9	<i>Porphyra</i> sp., <i>Catenella caespitosa</i> (R), <i>Padina crassa</i> , <i>Desmarestia aculeata</i> (P)	MAAs such as Aminocyclohexenone-type, Aminocyclohexene imine-type	Photoprotection, Antiaging, Anti-inflammatory, Antioxidant	[83]
10	<i>Curdiea racovitzae</i> , <i>Iridaea cordata</i> (R)	Palythine, asterina-330	Antioxidant, Anti-UV, Antiaging	[84]
11	<i>Porphyra</i> sp. (R)	Protein and hydrolysates	Moisture retention capacity and viscosifying agent	[85][86]
12	<i>Palmaria</i> sp., <i>Porphyra</i> sp. (R)	High amounts of Glycine and Arginine	Natural moisturizing factor	[87]
13	<i>Chondrus crispus</i> , <i>Mastocarpus stellatus</i> , <i>Palmaria palmata</i> (Figure 1g) (R)	Palythine, Usujirene, Porphyra-334, Shinorine, Asterina, palythinol	Antioxidant, Anti-proliferation	[88]

No.	Name of Macroalgae	Compounds	Cosmetic Benefits	References
14	<i>Pelvetia canaliculata</i> (P)	Amino acids	Antioxidant, Collagen synthesis, Proteoglycan synthesis stimulation	[89]
15	<i>Laminaria digitata</i> (Figure 1f) (P)	Proteins	Lipolytic	[90]
16	<i>Neopyropia yezoensis</i> (R)	Peptide PPy1	Anti-inflammatory	[91]
17	<i>Palmaria palmata</i> (Figure 1g) (R)	MAAs	UV protector	[92]
18	<i>Sargassum polycystum</i> (P)	Amino acids and amines	Anti-melanogenic or skin whitening effect	[93][94][95]
19	<i>Porphyra umbilicalis</i> (Figure 1i) (R)	Porphyra-334, Shinorine	Moisturization, Skin protector, Antiwrinkle, Protect against roughness	[96]
21	<i>Porphyra yezoensis</i> f. <i>coreana</i> (R)	Peptides, PYP1-5, porphyra-334	Enhance Elastin and collagen formation, reduce MMP expression	[96]
22	<i>Palmaria palmata</i> (Figure 1g), <i>Porphyra umbilicalis</i> (Figure 1i) (R)	MAAs	Antiaging, Collagenase inhibition	[97][98]

C, Chlorophyta; R, Rhodophyta; P, Phaeophyceae.

5. Pigments

Marine macroalgae have a broad diversity of photosynthetic pigments that capture light for the photosynthesis process. Chlorophyta (green algae) contain chlorophyll a, chlorophyll b, and carotenoids; Rhodophyta (red algae) contain chlorophyll a, phycobilin (phycocyanin, phycoerythrin), and carotenoids (carotene, lutein, zeaxanthin), and Phaeophyceae (brown algae) contain chlorophyll a, chlorophyll c, fucoxanthin, and different carotenoid pigments. Different macroalgae-derived pigments and cosmetic applications are reported in **Table 3**. These pigments provide a shield to the skin cells against harmful UV radiations [99].

Table 3. Applications of macroalgae derived pigments in skin cosmetics.

No.	Name of Macroalgae	Pigment	Cosmetic Benefits	References
1	<i>Sargassum</i> spp.	Carotenoids, Astaxanthin, Beta-carotene, Fucoxanthin	Anticellulite, Antiaging, Antiphotoaging, antioxidant, antiviral	[100]
2	<i>Saccharina japonica</i> (P)	Fucoxanthin	Inhibition of tyrosinase and Melanogenesis in UVB irradiated	[101]
3	<i>Cladosiphon okamuranus</i> (P)	Fucoxanthin	Antioxidant, DPPH inhibition	[102]
4	<i>Neopyropia yezoensis</i> ®	Phycoerythrin	Antioxidant, Anticancer, Antiinflammatory	[103]
5	<i>Gracilaria gracilis</i> , <i>Porpyridium</i> sp. (R)	Phycobiliprotein pigment such as R-phycoerythrin, Phycocyanin, Allophycocyanins	Antioxidant, Skin whitening activity by Antimelanogenic activity	[104]
6	<i>Cladophora glomera</i> ®(C)	Chlorophyll a, Chlorophyll b, Chlorophyll c, Chlorophyll d	Antibacterial, Antioxidant, Colorants, Deodorizer	[105][106][107]
7	<i>Portieri</i> ® p. (R)	Phycobiliproteins, Phycoerythrin, Phycocyanin	Antioxidants, anti-inflammatory, Colorants, Radical scavenger	[107]
8	<i>Cladophora glomerata</i> (C)	Chlorophyll	Tissue growth stimulators	[108]
9	<i>Neopyropia y[®]ensis</i> (R)	Porphyran	Antioxidant, Anti-inflammatory	[109]
10	<i>U[®] lactuca</i> (C)	Carotenoids such as astaxanthin, beta-carotene, fucoxanthin, lutein	Anti-inflammatory, Antiaging, Tyrosinase inhibition, Antioxidants, Photoprotective	[106]

No.	Name of Macroalgae	Pigment	Cosmetic Benefits	References
11	<i>Rhodophyta</i> (R)	Lutein	Skin whitening	[110]
12	<i>Paraglossum lancifolium</i> (R)	Lipid soluble pigments such as Xanthophyll and Carotenoids Beta-carotene, Lutein	Antioxidant, Anti-inflammatory, Antiphotoaging, Photoprotection, Anti-photoaging	[111]
13	<i>Undaria pinnatifida</i> (P)	Fucoxanthin	Photoprotective	[112]
14	<i>Porphyra</i> sp. (P)	Zeaxanthin, Alpha and beta carotene	Anti-inflammatory, Photoprotection, Antioxidant, Antiaging	[113]
15	<i>Gracilaria gracilis</i> (Figure 1k) (R)	Phycobiliproteins (R-phycoerythrin allophycocyanin, Phycocyanin)	Antioxidant	[104]
16	<i>Sargassum siliquastrum</i> (P)	Fucoxanthin	Skin protector, Antiphotoaging, Antirinkle	[114]
17	<i>Ulva lactuca</i> (C)	Zeaxanthin, Neoxanthin, Antheraxanthin, Siphonein, Siphoxanthin,	Photoprotection, Antiphotoaging, Anti-inflammatory	[115]
18	<i>Himanthalia elongata</i> (P)	Fucoxanthin extract	Antioxidant	[116]
19	<i>Ascophyllum nodosum</i> (P)	Fucoxanthin	Antiaging, Antirinkle	[117]
20	<i>Fucus vesiculosus</i> (P)	Fucoxanthin	Antioxidant	[118]
21	<i>Phaeophyta</i>	Fucoxanthin	Antiphotoaging	[119]
22	<i>Sargassum siliquastrum</i> (P)	Fucoxanthin	Anti-melanogenic (skin whitening effect), Antioxidant, Anti-inflammatory	[120]
23	<i>Gelidium crinale</i> (R)	Carotenoids	Antioxidant	[121]

C, Chlorophyta; R, Rhodophyta; P, Phaeophyceae.

6. Phenolic Compounds

Phenolic compounds are one of the secondary metabolites that make an important group of components for skin cosmetic benefits. Due to wide varieties of biological actions, they can be incorporated in various skin cosmetic preparations. They can be categorized into simple phenolic compounds and polyphenols, comprising bromophenols, phlorotannins, flavonoids, terpenoids, etc. [122]. Marine macroalgae derived phenolic compounds and their cosmetic benefits are presented in **Table 4**.

Table 4. Applications of macroalgae derived phenolic compounds in skin cosmetics.

No.	Name of Macroalgae	Phenolic Compound/s	Characterization or Analysis of Phenolic Compounds	References
1	<i>Macrocystis pyrifera</i> (P)	Phlorotannins, Phloroecdol, Tetrameric phloroglucinol	Antioxidant, Antidiabetic, Antiaging	[123]
2	<i>Ascophyllum nodosum</i> (Figure 1o) (P)	Ascophyllan	MMP inhibition	[124]
3	<i>Cystoseira foeniculacea</i> (P)	Polyphenol	Antioxidant	[125]
4	<i>Stephanocystis hakodatensis</i> (P)	Phenol	Antioxidant	[126]
5	<i>Ecklonia cava</i> subsp. <i>Stolonifera</i> (P)	Fucofuroecdol-A	Protection against UVB radiation	[127]
7	<i>Corallina pilulifera</i> (R)	Phlorotannins	Antiaging, antiinflammatory, antioxidants, antiallergic, UV screens	[128]

No.	Name of Macroalgae	Phenolic Compound/s	Characterization or Analysis of Phenolic Compounds	References
8	<i>Ishige foliacea</i> (P)	Phlorotannin	Antimelanogenic, inhibition of tyrosinase and melanin synthesis	[129][130]
10	<i>Laminaria ochroleuca</i> (P)	Polyphenol	Antioxidant	[131]
11	<i>Caulerpa racemo</i> ®(C)	Flavonoids, Hydroquinone, Saponins	Tyrosinase inhibitor	[132]
12	<i>Ecklonia cava</i> (P)	Dioxinodehydroeckol	UV B protective	[133]
13	<i>Ecklonia cava</i> subsp. <i>stolonifera</i> (P)	Phlorotannins	Inhibition of Matrix metalloproteins (MMPs), Antiwrinkle, Tyrosinase inhibitor, Skin whitener	[134]
14	<i>Saccharina latissima</i> (P)	Phenol	Antioxidant	[135]
15	<i>Ecklonia cava</i> (P)	Dieckol	Anti-adipogenesis	[136]
16	<i>Ecklonia cava</i> subsp. <i>kurome</i> (P)	Phlorotannin	Anti-inflammatory, Hyaluronidase inhibition	[137]
17	<i>Caulerp</i> ®p. (C)	Flavonoids, Phenols	Tyrosinase inhibitors	[138]
18	<i>Rhodomela conf</i> ®oides (R)	Polyphenol, Bromophenol	Antioxidant, Antimicrobial, DPPH inhibition	[139]
19	<i>Eisenia bicyclis</i> , <i>Ecklonia Cava</i> subsp. <i>stolonifera</i> (P)	Eckol	Anti-inflammation, Skin whitening activity	[140][141]
20	<i>Schizymenia dubyi</i> (Figure 1c) (R)	Phenol	Anti-melanogenic, Tyrosinase inhibition	[142]
21	<i>Cystoseira compressa</i> (P)	Fuhalol	Antioxidant	[143]
	<i>Cystoseira compressa</i> (P)	Fuhalol	Antioxidant	[143]
22	<i>Ecklonia cava</i> (P)	dieckol	Promotes hair growth	[144]
23	<i>Fucus vesiculosus</i> (Figure 1a), <i>Gongolaria nodicaulis</i> , <i>Ericaria selaginoides</i> , <i>Gongolaria usneoides</i> , <i>Ecklonia cava</i> (P)	Phlorotannins such as Fucophloroethol, Fucodiphloroethol, Fucotriphloroethol, Phlorofucofuroeckol bieckol or dieckol	Skin whitening effect, Antioxidant, Anti-inflammatory, Antihistamine, Photoprotection	[145]
24	<i>Ascophyllum nodosum</i> (Figure 1o) (P)	Phlorotannins, Eckols, Fucols, Phlorethols	Inhibition of tyrosinase, Anti-inflammation, Anti UV, Anti-allergic, Chelators, Antiaging, Hyaluronidase inhibitor	[145]
25	<i>Meristotheca dakarensis</i> (R)	Glucosaminoglycan	Anti-aging, Collagen synthesis	[12]
26	<i>Gongolaria nodicaulis</i> , <i>Ericaria selaginoides</i> , <i>Gongolaria usneoides</i> (P)	Phlorotannins such as bioeckol, 7-phloroeckol, phlorofucofuroeckol, fucophloroethol	Anti-inflammation, Antioxidant, Anti-aging, Inhibition of hyaluronidase	[145]
27	<i>Fucus spiralis</i> (P)	Phlorotannins	Inhibition of lipid peroxidation, hyaluronidase inhibitor, antiaging, antiwrinkle, Anti-inflammatory, Antiwrinkle	[145]
28	<i>Ecklonia cava</i> , <i>Ecklonia cava</i> subsp. <i>stolonifera</i> (P)	Eckol, 6,6'-bieckol, doeckol, Phlorofucofuroeckol-A, 8,8'-bieckol	Anti-allergic	[146]
29	<i>Eisenia bicyclis</i> , <i>Ecklonia cava</i> subsp. <i>stolonifera</i>	Phlorofucofuroeckol A	Hepatoprotective, Anti-tyrosinase	[147][148]
30	<i>Eisenia arborea</i> , <i>Ecklonia bicyclis</i> (P)	Phlorotannins	Anti-inflammation, Hyaluronidase inhibitor, antiwrinkle	[149]
31	<i>Eisenia arborea</i> (P)	Phlorofucofuroeckol A	Anti-allergic	[150]

No.	Name of Macroalgae	Phenolic Compound/s	Characterization or Analysis of Phenolic Compounds	References
32	<i>Ascophyllum nodosum</i> (Figure 1o), <i>Fucus serratus</i> , <i>Himanthalia elongata</i> (Figure 1h), <i>Sargassum muticum</i> (P)	Phlorotannins	Antioxidant, Antibacterial, antiviral, photoprotection, Anti-inflammatory	[151][152][153]
33	<i>Ecklonia cava</i> (P)	Eckols, fucols, phlorethols, Fuhalols, fucophlorethol	Anti-aging, Anti-inflammation, Hyaluronidase inhibitor, antiallergic, UV protector	[153]

C, Chlorophyta; R, Rhodophyta; P, Phaeophyceae.

7. Fatty Acids

Seaweeds are well known for various types of fatty acids such as glycolipids, triglycerides, sterols, and phospholipids. The chemical structures of marine algae derived fatty acids are illustrated in **Figure 7**. These have been reported as being higher in seaweed as compared to terrestrial plants. Different types of fatty acids from different macroalgae and its cosmetic benefits are presented in **Table 5**.

Table 5. Applications of macroalgae derived lipids and fatty acids in skin cosmetics.

No.	Name of Macroalgae	Fatty acid	Cosmetic Benefits	References
1	<i>Chondrus crispus</i> (R)	EPA, AA, DHA, GLA, LA, Palmitic acid, Oleic acid	Antiallergic, Anti-aging, Anti-inflammation, Antirinkle, Antimicrobial, Emollients,	[154]
2	<i>Undaria pinnatifida</i> (Figure 1b) (P)	PUFA	Anti-inflammatory	[154]
3	<i>Ulva lactuca</i> (Figure 1n) (P)	Fatty acid such as C18 and C16 type	In-vitro and in-vivo Nrf2-ARE activation, Cell protective, Antioxidant	[155]
4	<i>Phaeophyceae</i> (Brown algae) (P)	Unsaturated Fatty acids	Antioxidant	[156]
5	<i>Ulva lactuca</i> (Figure 1n) (P)	Lipopeptides	Inhibition of elastase, enhance collagen synthesis	[157]
6	<i>Himanthalia elongata</i> (Figure 1h) (P)	Fatty acids and volatile compounds	Antioxidant, Antimicrobial	[158]
7	<i>Porphyridium purpureum</i> (R)	Eicosapentaenoic acid, Docosahexaenoic acid, Eicosatetraenoic acid, Polyunsaturated omega-3 fatty acids	Antioxidant, Anti-inflammatory, Anti-photoaging	[159]
8	<i>Ulva rigida</i> (C), <i>Gracilaria</i> sp. (R), <i>Fucus vesiculosus</i> (Figure 1a), <i>Saccharina latissima</i> (P)	Lipidic profile	Antioxidant	[160]
9	<i>Sargassum fusiforme</i> (P)	Fucosterol	Protection against photodamage, UVB protector, MMP inhibition, Enhance procollagen formation, Anti-inflammatory	[161][162]
10	<i>Gracilaria longissima</i> (R), <i>Saccharina japonica</i> (P)	(8E)-10-oxo-8-octadecenoic acid, (E)-9-oxo-10-octadecenoic acid, Myristic acid, Palmitic acid	Anti-inflammatory	[163]
11	<i>Silvetia siliquosa</i> (P)	Fucosterol	Antioxidant, Stimulate antioxidant enzymes such as catalase, glutathione peroxidase	[164][165]
14	<i>Sargassum fusiforme</i> (P)	Fucosterol	Anti-aging, MMP inhibition	[166]
15	<i>Codium fragile</i> (C)	Sterol	Anti-inflammatory	[167]

8. Minerals

Depending on the environment in which macroalgae inhabit, they are highly diversified in mineral composition (especially with regards to trace elements including zinc, magnesium, aluminum, silica, copper, iodine, selenium, iron, manganese, and micronutrients including calcium, sodium, phosphorus, potassium, and chlorine).

Minerals have a very essential vital role as cofactors of different metalloenzymes [168]. Moreover, a combination of calcium and magnesium improves barrier repairs in topical skincare products [169]. Indeed, acid-induced burns are relieved by gel solution containing calcium gluconate solution [170]. Likewise, magnesium silicate (talc) and magnesium sulphate (i.e., Epsom salts) have reported enhancement of skin benefits. Talc is most frequently useful in baby skin powders to prevent diaper rash. In adults, it can be used as a lubricant and to reduce wetness in the perineal and axillary areas [171]. In addition, Boisseau et al. [172] found improvements in skin softness and exfoliation, relief in muscle tension, and the promotion of relaxation by Epsom salts. They also reported the key regulatory role of Mg⁺⁺ and Ca⁺⁺ in the proliferation and differentiation of keratinocytes. Likewise, magnesium silicate (talc) and magnesium sulphate (Epsom salts) have reported enhancement of skin benefits.

Talc is most frequently useful in baby skin powders to prevent diaper rash as well as in adults to reduce wetness in the perineal and axilla areas (and as a lubricant) [173]. They also reported the key regulatory role of Mg⁺⁺ and Ca⁺⁺ in the proliferation and differentiation of keratinocytes. ZnO-based skin protectants are cost-effective, easily formulated, and stable under aerobic conditions [173][174]. Zinc oxide is superior to zinc sulphate to mitigate inflammation and enhance re-epithelialization of partial-thickness porcine skin [175]. Due to low water solubility, it sustains in the skin at the wound site. Newman et al. [176] revealed the importance of skin in sunburned skin and under ultraviolet exposure. Bissett et al. [177] found significantly delayed UV-induced tumors in Guinea pigs and mouse models by topical use of a 2-furildioxime (iron chelator).

9. Summary

Macroalgae are a valuable resource of bioactive components, with scientific evidence revealing their benefits for safer use in humans and wellbeing. Marine algae-derived molecules showed biological effects on the skin, such as skin whitening, antiaging, antiwrinkle, photoprotection, moisturizing, and collagen-boosting, anti-inflammatory, antimicrobial, anticellulite, antiviral, and anticancer activities. Moreover, many cosmeceutical companies already use marine algae extracts and have derived compounds from these extracts in their formulations. However, the biochemical profile monitoring of macroalgae presents a problem that industries need to overcome. The development of its cultivation and sustainable methods of extraction procedures shows the significant key for this confined, which is being analyzed with noteworthy benefits. However, more detail analysis requires to understand the exact mechanism of some compounds since some compounds have not been fully explored. Therefore, the further analysis and evaluation are essential to improve the quality of cosmetic formulations which will be useful to enhance consumers safety.

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