

(RESEARCH ARTICLE)



## Revelation the sea's secret: Seaweed's rise as a potent cosmetic ingredient

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### Abstract

Due to their bioactive compounds with beneficial properties, seaweeds have high potential in cosmetics science and they are highly appreciated not only because of variability but due to a multitude sources. In this review, we have elaborated on the multifaceted roles of seaweed-derived ingredients used in skin and hair care formulations focusing both on their biological components as well as extraction processes resulting in therapeutic properties. Here, the effectiveness of seaweed extracts in moisturising, anti-ageing and sun protection applications are discussed as well as sustainability and suggestions for future directions. This review highlights the importance of seaweeds establishment as a natural ingredient, effective properties and expected sustainability on contemporary cosmetic formulations through state-of-art scientific evidence providing promising ways to modernizing processes in the beauty industry.

**Keywords:** Seaweed; Cosmetics Science; Skincare; Haircare; Bioactive Compounds; Extraction Methods; Sustainability; Anti-Aging; Moisturizing; Natural Ingredients

### 1. Introduction

Seaweed, large forms of marine algae known as macroscopic species that grow in the oceans all over the world and are also used by humans for hundreds or thousands of years across multiple cultures due to its demonstrated health benefits. The remarkable attention which seaweed has gained over the last decades in cosmetics industries is due to its rich bioactive component, that gathers a veritable treasure of properties for healthy skin and hair. In this Study Guide, we provide an introduction to understanding the several functions that seaweed can play in cosmetics science-its composition (the biological activity of its components); different methods employed for extracting these compounds used in cosmetic applications; and overview on sustainability concerns.

Historically, in traditional coastal communities, seaweed has been a crucial element as far as the practice of medicine and skincare are concerned; its abundant occurrence in nature and wide-ranging chemical composition have made it possible for people to exploit it for treatment. However, at present times, scientific investigation has disclosed the existence of several bioactive molecules that are found in seaweed such as polysaccharides e.g. alginate and carrageenan, proteins, vitamins (like A,C,E), minerals (such as iodine and calcium) and omega- 3 fatty acids which are essential. These constituents help in conferring anti-oxidant properties on seaweed, reducing inflammation, moisturizing effects together with being anti-aging agents hence making them useful ingredients for manufacturing cosmetics.

Extraction of bioactive compounds from seaweed shows several methods like solvent extraction, aqueous extraction and modern methods like super expensive liquid extraction Each method affects the yield, purity and bioactivity of the extracted compounds, and by does influence their effectiveness when encapsulated skin care and hair care products of drying and encapsulation Processing methods improve the stability and bioavailability of seaweed-derived products.

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Seaweed extracts are known to increase skin hydration, firmness and protection against UV rays and other environmental stressors. These ingredients provide the seaweed extract is best added to skin moisturizers, serums, masks and cleansers aimed at tackling a range of skin problems from dandruff, inflammation to premature aging. Drugs derived from sugar give head nourishes hair, Strengthens hair roots, gives hair texture and shine, and provides solutions to issues such as hair fall and damage.

There is more to seaweed than meets the eye. Though mostly used in beauty products, studies now show that it can be effective in managing skin issues such as acne, eczema and psoriasis. As a result of its anti-inflammatory and antimicrobial activities, seaweed could act as both a remedy for better skin and a beautifying agent at the same time. This natural wonder promises future possibilities of targeted remedies and general skin well-being; therefore leading us into a new phase of skincare.

In addition, as the earth becomes more concerned about environmental sustainability, locating and growing seaweed in a way that is friendly to the environment has become a norm in the manufacture of cosmetics. Sustained harvests and aquaculture processes are designed to make seaweeds a renewable resource that can be tapped without causing much harm to the environment while catering to consumer needs for healthy and safe beauty components through natural means.

Based on the above insights, the combination of seaweed and cosmetic solutions reflects the coming together of traditional knowledge, scientific innovation, and ecological praxis. With the unceasing uncovering of new bioprocesses and the steady technological progress in extraction and processing, the demand for seaweed continues to grow various fields of skin care, hair care, and dermatology; thus, manufacturers will have access to their services. The main objective of this paper is to supplement the current knowledge and show what further development can be exploited by this microscopic organism in the change of cosmetic materials production, especially the very foundation of sustenance.

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## 2. Biological Components of Seaweed

Macroalgae, namely seaweed, is an extensive variety of plant organisms in the sea which are originated from Asia to Europe. They have a distinctive multicellular structure and use the energy from the sun to make their own energy via photosynthesis. There are three classes of seaweeds which are primarily distinguished based on pigment and photosynthetic pigments: brown algae (Phaeophyceae), red algae (Rhodophyta), and green algae (Chlorophyta). Each of them is composed of biologically special parts, which help them in synthesizing bonds between the plants and forcing them to produce the drugs.

### 2.1. Polysaccharides

Seaweed has contained in carbohydrates that are linked to a specific function and the storage of structures in its cells. These polysaccharides include:

**Alginate:** Most of the time you find alginate in brown algae, and one remarkable thing about it is that it is a gelling agent and retains water similarly and it is popularly used in cosmetics mainly because of its moisturizing and allying effects.

**Carrageenan:** It comes from red algae and is a sulphated polysaccharide with thickening and stabilizing effects to formulations as well as cosmetic creams and lotions.

### 2.2. Proteins and Amino Acids

Among other nutrients, seaweed are filled with proteins and amino acids that are essential for both cell functioning and structural support. These proteins include the glycine-rich substances as well as some amino acids that make the algae less affected by environmental stressors and contribute to its skin and hair health. The particular nature of these living organisms is that they are glycine-rich proteins and some amino acids which together with the rest of the component's biopolymer protection make the algae withstand even the hardest environmental conditions, such as UV irradiation and harmful chemicals.

### 2.3. Vitamins and Minerals

Seaweed is beneficial to health and skin care naturally, as it is full of vitamins and minerals. Seaweeds such as vitamin A (retinol), vitamin C (ascorbic acid), and vitamin E (tocopherols) are the most commonly found. They have antioxidant

properties that help fend off free radicals that damage the skin and lead to the early signs of aging. Besides those minerals, the seaweed also contains iodine, calcium, magnesium, and potassium that are the most important ones and they are also responsible for the nutritional and medicinal benefits.

#### **2.4. Polyphenols and Phlorotannins**

According to the biomedical database, polyphenolic compounds are found in seaweed which contain flavonoids and phlorotannins that are strong antioxidants and anti-inflammatory agents. These are the compounds that protect the skin cells from oxidative stress, they also help to reduce inflammation, and at the same time, they promote collagen synthesis, attributing to anti-aging effects in cosmetic applications.

#### **2.5. Essential Fatty Acids**

Seaweed serves as a source of vital fatty acids, such as omega-3 and omega-6 fatty acids, which are vital for one's skin barrier function and hydration. These fatty acids provide the skin and hair with the necessary nutrients for improved moisture retention and better overall health.

#### **2.6. Other Bioactive Compounds**

Seaweed also contains a variety of other bioactive compounds such as phycobiliproteins (in red algae), terpenes, and sterols, each with specific biological activities that contribute to the algae's therapeutic potential in skincare and haircare formulations.

Seaweed's biological components jointly offer a wide range of cosmetic benefits including moisturizing, antioxidant, anti-inflammatory, and anti-aging. As the studies uncover the interrelation between these bioactive compounds and their effects on the health of hair and skin, the seaweed continues to be a significant and sustainable cosmetic science livestock.

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### **3. Extraction and Processing Methods**

The process of extracting and formulating seaweed for cosmetics utilize multiple methods that are developed to capture the bioactive properties of this raw material, as well as maintain its safety and efficacy in finished products. These assays are used for assessment of quality, stability and bio accessibility or seaweed-derived ingredients.

#### **3.1. Extraction Techniques**

**Aqueous Extraction:** This method consists of soaking the seaweed biomass in water to extract other compounds-like polysaccharides, proteins and some antioxidants-that are not considered amphipathic molecules. Aqueous extraction is environmentally friendly but simple and does not effectively extract lipophilic (fat soluble) one.

**Solvent Extraction:** Pure solvents such as ethanol, methanol or acetone are used to dissolve lipophilic compounds out of seaweed biomass. This method enables more extraction of bioactive compounds, particularly polyphenols and essential oils. Nonetheless, much care should be taken in the choice and control of solvent since it can lead to contamination so processes need suitable solvents for reasonable release.

**Supercritical Fluid Extraction (SFE):** SFE employs supercritical fluids - usually carbon dioxide (CO<sub>2</sub>) at an appropriate temperature and pressure state to extract bioactive compounds from seaweed. This approach is useful for the isolation of heat-sensitive compounds and provides good selectivity as well purity. Finally, totally non-toxic CO<sub>2</sub> can be regarded as environmentally friendly solvent and also latter could be recycled in the closed loop of SFE.

**Microwave Assisted Extraction (MAE):** MAE applies microwave radiation to the solvent in parallel with moderate temperatures accompaniments and cut down extraction time. This method saves the time of extraction, is energy efficient and also enhanced yield of bioactive compounds from seaweed biomass.

**Enzyme-Assisted Extraction:** Enzymes, like cellulases and protease can be used to hydrolyse cell walls releasing bioactive molecules from seaweed. It has mild and accurate methods ensuring that it extractives highly volatile as well some other more delicate compounds in the extraction.

### **3.2. Processing Techniques**

Drying-extract and biomass for seaweed should be dried post extraction to eliminate the extra water, helps active ingredients stable. These methods comprise air drying, freeze-drying (lyophilisation) and spray drying improving the preservation of bioactivity as well its shelf-life.

Grinding and Milling: Grinding or milling to reduce the seaweed biomass particle size for achieving homogeneity before proceeding into other process such as cosmetic formulation.

Encapsulation: Seaweed extracts can be encapsulated for improved stability and controlled release of bioactive compounds e.g. microencapsulation or nano-encapsulation Encapsulation is a protective technology that encapsulates raw materials in microcapsules with polymer layers to prevent their loss due to degradation, oxidation and environmental factors during use of cosmetics.

### **3.3. Quality Control and Safety**

Finally, a quality control needed all along the process as well at final product of seaweed extract preparation to cosmetic use has to provide their safety, high grade quality and reproducibility. This can include testing for potential contaminants, quantifying bioactive content and profiling stability under different storage environments.

### **3.4. Sustainability Implications of our Choices**

Given the escalating demand for seaweed in cosmetics and other consumer industries, depletion would be disastrous. Sustainable harvesting techniques must be used on a commercial scale when cultivating seaweed to ensure minimal pressure is placed onto wild stocks and the marine environment whilst following aquaculture practices would maximize quality through controlled environments of an artificial feedstock.

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## **4. Seaweed in Skincare**

Its rich content of bioactive substances and multiple health-benefiting effects for the skin have made seaweed a sought-after ingredient in cosmetics. Seaweed extracts are added in a variety of skincare products to enhance their efficacy and also the appeal (hydration, anti-aging activity, soothing properties etc.)

### **4.1. Hydration and Moisturization**

Seaweed extracts are reputed for being of the most hydrating substances in a skin care formula, largely due to polysaccharides such as alginate or carrageenan. It is these compounds that aid in keeping the moisture locked into skin, thereby strengthening its barrier and limiting any loss of water. Thus, skin care products with seaweed extracts (seaweed serums and moisturizers) provide hydration to dry or dehydrated complexions rendering in a hydrated texture.

### **4.2. Anti-Aging Effects**

Antioxidants are one of the essential derivatives present in seaweed; they include vitamins A, C, & E as well as polyphenols and phlorotannins. Seaweed's natural antioxidants work to eliminate free radicals which are essential to help reduce premature aging of skin marked by fine lines and wrinkles along with age spots. Additionally, seaweed extracts help in combating oxidative stress, which in turn promotes collagen synthesis and elastin production. As a result, the skin enhances its elasticity and firmness. Anti-aging creams and serums use all of these characteristics to rebuild youthful appearance on the skin.

### **4.3. Soothing and Anti-Inflammatory Properties**

The components derived from the marine alga include fucoidan and laminarin which aids in reducing inflammation and swelling of the skin. Seaweed is therefore best suited for skin types that are very sensitive or persons suffering from skin conditions such as eczema or rosacea. Cosmetics containing seaweed as active ingredients allow skin cooling effect and make the skin tone more appropriate.

### **4.4. Protection Against Environmental Stressors:**

Seaweed extracts include various natural active substances that give it anti communicating properties against aggressors affecting the skin, for instance, UV radiation and pollution. For example, the carotenoid found in brown algae

known as fucoxanthin has photo protective activity which can protect the skin from UV damage. Seaweed based sun tan lotions and day care creams help to strengthen the skin's natural barriers and are beneficial in the long run for the skin.

#### **4.5. Detoxification and Purification**

Some of the extracts derived from seaweed are beneficial in detoxifying the skin by 'cleansing' it from these toxic substances. This gratefully action aids in helping the pores, reduction in oil secretion and hence a better skin health is seen. Cosmetics with seaweed included in their composition are suitable for people whose skin is oily or prone to pimples; they cleanse the skin thoroughly but do not remove the natural oils from the skin surface.

#### **4.6. Enhanced Absorption of Nutrients**

Seaweed extracts work in the skin's natural processes to aid the skin in the absorption of other healthy components of skincare products. Seaweed extracts help to increase the absorption rate of vitamins, minerals and moisturizing agents improving the overall efficiency of the skincare products and thus the nourishment and revitalization of the skin.

The use of seaweed in skincare means it can be utilised in a wide variety of skincare regimes because it solves various skin problems. Seaweed remains at the forefront of breaking barriers in search for natural SKUs as consumer trends for green and organic beauty products are on the rise. Nonetheless, with last researches and innovations in the field, the possibilities of applying seaweed in skin-care products are positively tinted and represent momentary and further positive skin's impact for users globally.

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### **5. Seaweed in Haircare**

Seaweed which is popular for its contains and healing power has become famous in the hair care product as a natural ingredient that can benefit the hair follicles, the head skin, and the general power and texture of the hair. From hair shampoos and conditioners through hair masks and serums, the extracts obtained from seaweed contain a cocktail of nutrients that will address almost any hair complaint.

#### **5.1. Scalp Nourishment and Hydration**

Seaweed extracts are vitamins, mineral and amino acid which helps to treat dry and damaged skin on the scalp. All these nutrients work effectively in maintaining a healthy environment on the scalp through-blood circulation, sebaceous gland activity and moisture content. Consequently, various problems that affect the skin on the head like dryness, itch and flakiness are eased permitting head hair to develop.

#### **5.2. Strengthening Hair Follicles**

The proteins and the necessary amino acids that are available from the seaweed extract also help in the strength of hair strands. When the hair follicles become strong and hair shafts stronger, then breakage, split ends and hair loss are reduced, which is promoted by seaweed. Daily use of marine actives in hair care products fortifies the hair shaft right from the follicle to the tips giving hair a fuller and healthier appearance gradually.

#### **5.3. Improving Hair Texture and Shine:Improving Hair Texture and Shine**

Seaweed extract include natural polysaccharides and amino acids which when applied to the hair shaft provides a sheen to the surface of the hair, thus improving the all natural shine to the hair. They facilitate detangling, as well as give hair silkiness and manageability while at the same time minimizing on frizz. The hair that has been conditioned and/or treated with sea kelp based servums are shinier, brighter, and evidently healthier.

#### **5.4. Protection Against Environmental Damage**

Seaweed extracts have demonstrated antioxidants the ability to shield organism from environmental stress including heat/cold, UV, pollutants and oxidative stresses. Vitamin C and phlorotannins counter free radicals that compromise the hair fabric which results in dry and lack luster hair. These supportive measures for the hair shaft are part of the physiological armor that protects the hair from environmental stress and in the course of applying seaweed-based haircare products, hair health and vigor are upheld.

### **5.5. Stimulating Hair Growth**

Red algae for example has bioactive properties which if used in stimulating the hair growth process as it enhances the blood flow to the head skin and feeds the roots. They can help to prolong the catagen phase thus helping to increase the number of hair follicles that are in the anagen phase and hence hair which is thicker and fuller.

### **5.6. Balancing Scalp pH and Oil Control**

Seaweed extracts have natural properties of balancing the pH of the water and since the skin of the scalp can have an excessively high pH level these components work to fix this. This balancing effect assists in maintaining a right production of sebum within the scalp to avoid a greasy hair line and provides the hair roots a much cleaner environment to germinate in. Seaweed extract used in hair care products brings disentangling action that allows moisturizing the hair without negatively influencing the scalp.

### **5.7. Detoxification and Cleansing**

Seaweed extracts are useful in cleansing the hair and the scalp of the impurities, pollutants, and other residual products. This process helps to clean up the follicles thus enhancing the health of scalp so that issues such as dandruff and irritation of the scalp are less likely to happen. The examples of seaweed-based clarifying shampoos and treatments work as proper cleansers for the hair with no impact on the hair's moisture.

The consumption of seaweed has long been proven to be beneficial to the hair and can be used as natural way of making hair healthier. Clearly, additional research on the application of various extracts of seaweed in hair and scalp care will demand the adoption of these marine organisms and their derivatives in hair care products, in response to the prevailing considerable demand for natural hair care remedies.

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## **6. Therapeutic Applications of Seaweed in Skincare and Dermatology**

For quite some time now, seaweed has proven to be densely loaded in nutrients and active agents that have been of value in cosmetic ability in treatment and dermatologic use. Dietary sources of the beneficial properties that can be present in seaweed make it a rather useful addition to deal with multiple skin issues and benefit the skin in general.

### **6.1. Anti-Inflammatory Properties**

The water soluble polymers in the form of fucoidans and phlorotannins present in the extracts from seaweed have been known to possess a powerful anti-inflammatory action. These compounds assist to eliminate redness, inflammation, soreness that are characteristic of the irritation conditions such as acne, eczema and psoriasis. After bath application and or massaging with seaweed based formulations is very effective in the treatment of sensitive skin, relieves inflammations and helps heals.

### **6.2. Antioxidant Activity**

Antioxidants in seaweed comprises of vitamins A, C and E; and polyphenols help in preventing the skin from oxidative forces such as UV rays and pollutants, among them. In addition to scavenging free radicals, seaweed extracts are effective in minimizing the onset of the earliest signs of skin aging such as fine lines, wrinkles, and skin discoloration. Consuming antioxidant rich seaweed products to keep one's skin healthy to give the appearance of younger looking skin.

### **6.3. Moisturizing and Hydrating Effects**

Among the components of seaweed there are polysaccharides, for example, alginate and carrageenan – they provide the excellent effect of moisturizing. It contributes a waterproof layer on the skin thus retaining the moisture content since it also reduces TEWL. Sulphate-rich facial creams and pack s in seaweed required skin tightening leaving it smooth and supple.

### **6.4. Wound Healing and Tissue Repair**

Seaweed extracts contain some undisputable compounds that stimulate the healing of wounds and tissue formation. Substances such as laminarin and fucoidans contribute to the formation of collagen which is essential in wound healing as well as the doubling rate of cells and the formation of new blood vessels in the wound site also known as angiogenesis.

These qualities also ensure that seaweed has healing properties for wounds, cuts and burns thus resulting to faster healing process and little scar tissue formation.

### **6.5. Anti-Microbial and Anti-Acne Properties**

The sea kelp also contains antimicrobial properties with suppressing the bacteria/fungal responsible for acne spots and skin infections. Some of the treatments containing seaweed extracts alleviate acne products by inhibiting bacterial growth and reducing redness and inflammation, reducing the number of lesions, and regulating sebum levels while also enhancing skin clarity. These products should be used daily in order to avoid tackiness or oily skin that leads to acne formation and to maintain a nicer skin.

### **6.6. Skin Brightening and Pigmentation Reduction**

Some seaweed species possess some ingredients that restrain melanin synthesis and assist in erasing the chloasma resulting from sunburning or postinflammatory hyperpigmentation. Skin brightening properties bestowed by carotenoids help to overcome the dark and pale regions, minimize the grouping of melanin and therefore help skin to gain luminous properties.

### **6.7. UV Protection and Photoprotection**

Fucoxanthin, a carotenoid compound found in the brown algae has active role in acting as a natural sunscreen, thus providing the UV protection by absorbing the damaging ultraviolet radiation that harms the skin cells. A number of seaweed extracts are used as photoprotective agents and prevent sun aging, sunburn and DNA injury, thus it is useful for the long-term sun protection of the skin and decreased chances of skin cancer.

Using the ingredients obtained from these sea plants, therapeutic skincare products can be formulated to allow skin disorders to be managed naturally apart from improving the skin health. It is possible to note that as scientific work expands the opportunities of using seaweed in dermatological practice, the production of specialized preparations and cosmetic products based on its components is also planned to increase, which will guarantee a high quality of addressing various skin issues.

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## **7. Sustainability Considerations in Seaweed Utilization for Cosmetics**

The awareness of the need for natural and environmentally friendly biomaterials has made the focus on seaweed as one of the sea's valuable resources in producing cosmetics. But the sustainable gathering, farming, and production of seaweed are important for environmental conservation and to avoid that can threaten the future of marine life.

### **7.1. Harvesting Practices**

In sustainable harvesting, efforts are made to reduce harm done so as to maintain the stocks of seaweed in the ecosystems. Techniques like hand-harvesting, mature plant harvesting and rotational harvesting helps in reducing the impact on Biodiversity and seaweed also get to reproduce naturally. The harvesting quotas and the seasonal restrictions also limit the extraction activities in order to avoid degrading the marine ecosystem.

### **7.2. Aquaculture and Farming**

Seaweed aquaculture or more specifically seaweed farming can be described as a controlled farm system that involves the growing of seaweed species. Agritourism helps in the management of farmland, conserving natural resources, natural population, jobs opportunity, and income generation. IMTA, such as seaweed growing together with fish or shellfish, improves the final product of the natural resource and optimizes the recycling of nutrients as well as the overall environmental impacts.

### **7.3. Biodiversity and Ecosystem Health**

Sustainable harvesting and farming of seaweed include the health of the ecosystem and protection of the bio-diversity status. Supervisory and investigative programs evaluate the effects of seaweed production on the overall environment, so that the culture does not threaten to degrade sensitive ecological niches or the habitats of endangered species. Efforts for conservation involve strictly the protection of areas with diverse species and the preservation of the marine ecosystems.

#### **7.4. Environmental Footprint**

The effect of carbon footprint and a number of environmental factors in the extraction of seaweed, its processing and transportation are looked at in the sustainable methods. Concerning the environmental impacts of the products, measures to increase efficiency of energy consumption and emissions of greenhouse gases, as well as to modify the environmental impacts of the processing technologies (for example, the use of renewable energy and reducing of waste) influence the decrease of the environmental impacts for the supply chain.

#### **7.5. Regulatory Compliance and Certification**

Observance of national and global legal requirements concerning marine resources, and the legalities of seaweed gathering/production also promotes sound production techniques for seaweed and marine plants. Organic certification and sustainability certifications, for instance, the Marine Stewardship Council, Ascribe-now certified seaweed standard offer information about sustainable sourcing and traceability from the point of origins.

#### **7.6. Community Engagement and Social Responsibility**

Levellized seaweed practices focus on community involvement and social aspects as the management of native partnerships with locals and first nations. Labour rights, assigning priorities to resources, and economic impacts from seaweed farming are pushing towards sustainable community and culture conservation.

#### **7.7. Research and Innovation**

Ongoing studies and technological developments contribute to the improvement of sustainable growing, production and application of seaweeds in cosmetics. Intersectorial researches with universities, industries, and governmental institutions dedicate to find new ways for cultivation and genetics biodiversity preservation, as well as bioactive compounds for cosmetic uses to improve the cosmetic sustainability.

In that sense, it is possible to encourage stakeholders and the cosmetic industry to incorporate sustainability aspects in the use of seaweed for cosmetics, thus being able to protect the marine environment, the communities relying on it for their livelihoods and also answer consumer concerns about sustainability. Adopting sustainable practices serve the purpose of preserving the earth's natural resources as well as empowering industries such as the cosmetics industry to look for creative way of creating more sustainable products.

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### **8. Future Directions**

The potential of seaweed as a resourceful and consciously friendly material to fashionable cosmetics is rather great; applying its properties to skin care, hair care, and some therapeutic purposes. As research and technology continue to advance, several future directions can shape the utilization of seaweed in cosmetics:As research and technology continue to advance, several future directions can shape the utilization of seaweed in cosmetics:

**Advanced Extraction Technologies:** Future work for overcoming the challenge in efficient extraction of bioactive compounds from seaweed includes, supercritical fluid extraction, enzymatic extraction. These are key developments will enhance the design high-performance cosmetics that are more effective in skin treatment and easier to penetrate skin barrier.

**Biotechnological Innovations:** Employment of genetic engineering and metabolic engineering of the seaweed species can pave way for the synthesis of bioactive compound with requisite skin treatment effects. In the processing of seaweed, it is also possible to attain high degrees of resource efficiency and low degrees of waste through biorefinery processes.

**Personalized Skincare Solutions:** The future of personalized skincare will build upon the likeliness of incorporating more seaweed-based products to better tailor for the skin issues of each client. Formulation personalized by genetic and skin microbiome, will enhance treatments responses and consumers satisfaction.

**Sustainability and Ethical Sourcing:** As it has been demonstrated in the current business models, the cosmetics industry will remain conscious about sustainability of the sources of Seaweed biomass. Measures like certification, traceability, and cooperation with communities will help to practice sustainable procurement and become allies to nature.



Clinical Validation and Regulatory Frameworks: More clinical studies and efficacy trails will give a rather scientific evidence of the therapeutic use of seaweed in beauty products. Existing and future protective legislations will be put in place for safe, effective and quality cosmetics that use ingredients derived from seaweeds.

Consumer Education and Awareness: A well-informed customer that has understood the importance of seaweed in the cosmetics industry, how it can be sourced sustainably with the supposed benefits it is expected to have on the skin will create the market as much as it was anticipated for environmentally-friendly makeup products. Communication and Labelling will also entail presentation of information with labels to be made to the public in a manner that will enable the consumers be informed.

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## 9. Discussion

All in all, seaweed can be considered as an organic and eco-friendly product that has significant applications in connection with cosmetic studies. Seaweed has these many bioactive compounds that make it very effective in skin and hair treatments, so it is actually multi-purpose as it is pro-moisturizing, anti-ageing, anti-inflammatory and a shield. Seaweed is likely to be a major influence on the future direction of cosmetic and personal care markets, and markets and the cosmetics sector will continue to change in their sustainability. For the full potential of seaweed to be realized, technology, similar to the responsible sourcing patterns, must be achieved, all in a bid to maintain the marine ecosystem and foster globalization goals.

Examining the migration path of seaweed from an ordinary maritime commodity to the current highly valued cosmetics product evinces the ever-relevant importance of this natural resource in the cosmetic industry and for the future of beauty and personal care that is green, healthier, and sustainable.

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## Compliance with ethical standards

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