Marine Bioactives: Effective Resources in Cosmetics

Pankhudi Sah[1], Neha Kale[2], Shashwati Mankar[3], Zahara Nasikwala[4], Nibha Bajpai[5], Deepak Wasule[6]
[1,2,3,4]*PG Student, Department of Cosmetic Technology, LAD College, Nagpur, 440006 Maharashtra, India*
[5]*Assistant Professor, Department of Cosmetic Technology, LAD College, Nagpur, 440006 Maharashtra, India*
[6]*Professor, Department of Cosmetic Technology, LAD College, Nagpur, 440006 Maharashtra, India*

***Abstract* —Great interest has been expressed in the cosmetic industry regarding the usage of marine-derived cosmetic active ingredients due to their numerous beneficial effects on human skin health. These are biologically active compounds resulting from natural organisms, which have ultimately given rise to the emergence of new and improved skin care products. It consists of various phytochemicals mutually grouped from various marine resources. Various new bio-active ingredients have been discovered lately from mineral resources with safe, stable, and notable effects on human skin, characterized as anti-inflammatory, anti-aging, skin-whitening and brightening, sun-screening properties, etc. A growing number of novel compounds from marine flora and fauna exhibit potent and effective dermatological activities. With the advancement in the biotechnological field observed in the marine industry, an increase in the use of marine-derived bio-actives has been observed over the last few years which finds a wide spectrum of usage in the cosmetic industry.**

***Keyword*— Bioactive compounds, Bio affinity, Blue-biotechnology, Marine cosmetics, Skincare.**

I. INTRODUCTION

Skin, the largest organ of the body protects against various external stimuli and damage. The three main layers of skin; are epidermis, dermis, and hypodermis, out of which the superficial horny layer comes in direct contact with cosmetics. The epidermis consists of melanocytes which produce the pigment melanin, Langerhans cells with immune response functions. The dermis is composed of connective tissue. The basic materials comprise the extracellular matrix consisting of glycosaminoglycans and fibrous proteins. In the skin, hyaluronic acid and dermatan sulfate are common forms. While intrinsic skin aging results from the passage of time and genetic factors which give rise to wrinkles, dryness, and loss of elasticity, extrinsic skin aging results from exposure to pollutants or UV radiation.[1] Atopic dermatitis, wrinkling, aging, and various other skin-related disorders are common problems faced these days. To treat these disorders, products especially from the marine origin are now more in focus.

Oceans covering more than 70% of the world's surface are a valuable source of chemical compounds. At present, more than 7000 marine products have been isolated, out of which 25% are from algae, 33% from sponges, 18% from coelenterates, and 24% from other invertebrate phyla.[2]

II. ACTIVE INGREDIENTS FROM MARINE SOURCES USED IN COSMETICS

High demand from the cosmetic industry for bioactive compounds led to the development of improved and advanced techniques for their harvest and production. The superiority of marine cosmetic actives comes from their exceptional bio-affinity with the internal environment of the body, making them more effective in action.[3] These are a few examples of marine sources for actives in cosmetics and they are also mentioned in Table. 01.

1) Marine Sponges

Marine sponges represent a fascinating huge production of secondary metabolites. The marine sponge is a renewable natural resource.[4] The marine sponges are highly absorbent, create a luxurious lather, are softly textured, and are suitable for the most insightful skin. They are stronger and last longer than synthetic sponges due to abrasion. In addition, marine sponges are enhanced for bathing and cleaning because they soak up and hold more water without drenched. Mainly these are used for babies to clean their insightful skin. And also used as a skin whitening compound.[5]

Fig.1 Marine Sponge

2) Seaweed

Seaweed is also known as brown seaweed, red seaweed, algae, and Irish moss. Seaweeds are aquatic, photosynthetic organisms taxonomically categorized as algae. Since ancient times seaweeds are also used as an alternative medicine for skin-related diseases. Seaweed plays a major role in antioxidant, antitumor, anti-inflammatory, anti-lipedemic, anti-microbial, and also anti-allergic properties.[6] Seaweed is rich in mineral salts, amino acids, and Vitamins. This help reinstates the texture and tone of the skin and reduces the appearance of cellulite. Seaweed has been used in bath, body, and skincare products for many centuries to improve circulation and balance natural moisture levels.[5] Seaweeds are edible as well as biodegradable. They are naturally high in fiber and vitamins and can be turned into packaging without the need for chemicals.[7]

Fig.2 Seaweed

3) Shark liver and Turtle Oil

The oil obtained from marine animal sources have moisturizing properties. Shark liver oil is rich in omega-3 fatty acid with a principle component as squalene, a triterpenoid ($C_{30}H_{50}$), ranging up to 90% of the oil[8]. Turtle oil also contains fatty acids which can be extracted by heating turtle fat. Turtles have ripe old age, due to the oil in their bodies, and turtles were also thought to have exceptional powers of skin healing.[5] They are found in many products together with, moisturizers, deodorants, suntan lotion, lip balms, lipsticks, perfumes, shampoos, toiletries, and other cosmetics.

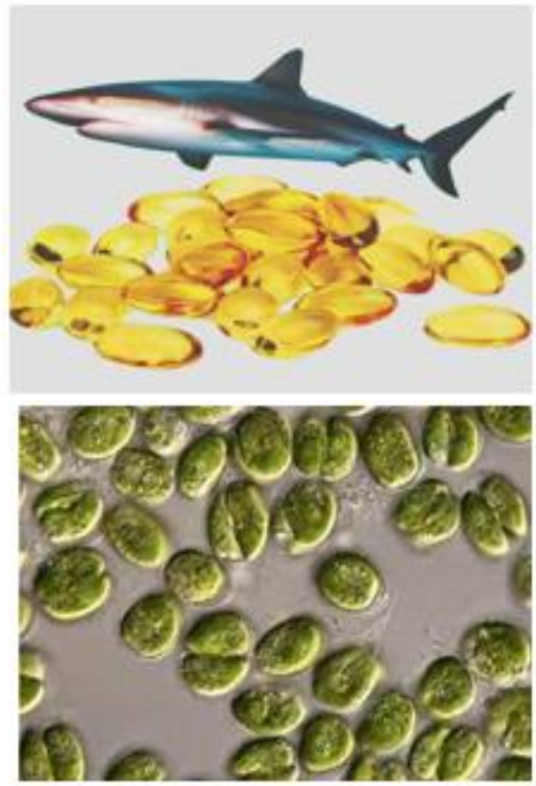

Fig.3 Shark liver oil

4) Coral

Coral reefs are called the rainforests of the Sea, both due to the vast number of species and the high productivity. Coral reefs support extraordinary biodiversity and are home to different types of fish, invertebrates, and sea mammals.[5] Coral powders have been used in numerous cosmetic products, being touted as copious and unique. The coral powder used as a new sustainable material for cosmetic applications is supported by its physical, chemical, and textural characteristics. The chemically coral powder is mostly calcium carbonate, it may contain 74 additional trace minerals, with the absence of heavy metals. This coral powder is used to protect from UV radiation and acts as an anti-oxidant, anti-aging, and anti-acne. It is used to smoothen the skin, in lipstick, powders, and deodorant preparations.

Fig.4 Coral-reef

5) Jellyfish

Jellyfish are mainly free-swimming marine animals with umbrella-shaped and trailing tentacles[9]. The epidermis and gastro dermis of jellyfish contain mucus-producing gland cells. Under stress, during reproduction, digestion, and when dying, the amount of released mucus is increased and can reach up to 400 mL/kg of jellyfish per hour.[10] The mucus formed by jellyfish is rich in a compound that is vital for cosmetics. Jellyfish have powerful antiaging properties. Cosmetic industries have helped to increase the fish stock by using jellyfish in the manufacture of anti-aging beauty products. It helps to treat and prevent DNA damage and persuade our skin cells to act young again and regenerate.[5]

Fig.5 Jelly-fish

6) Hydra

Hydra genus of invertebrate freshwater animals of the class Hydrozoa (*phylum Cnidaria*). The body consists of a thin, usually translucent tube (1.2 inches) long but is capable of great contraction.[11] Hydras mainly consist of a gel that consists of antioxidants and proteins. Mainly hydras are used in the preparation of lip products, makeup removers without any reaction, and also as a moisturizer. It contains Vitamin-C and Vitamin-E which are used in sunscreen lotions to protect from UV radiation and moisturizing cream. It is rich in olive oil with emollient properties.[5]

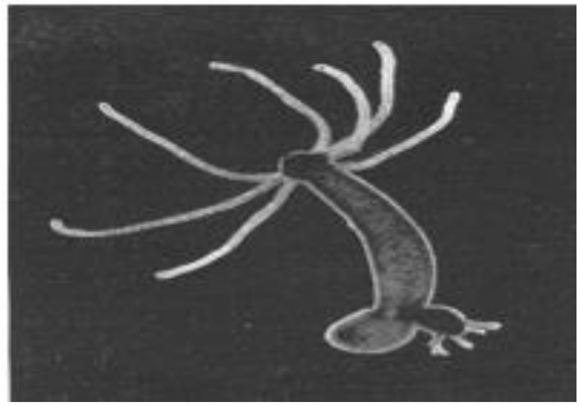

Fig.6 Hydra

Table. 1 Marine sources with their application in Cosmetics

Source	Properties	Application
Marine sponges	Highly absorbent, Create luxurious lather	Bath-product
Seaweed	Anti-oxidant, Anti-inflammatory, Anti-microbial, Anti-allergic	Bath-product, Skin-care product, Biodegradable packaging
Shark liver oil	Rich in fatty acid	Skin and lip care products, Sunscreen
Sea turtle oil	Skin-healing	Bath-product, Perfume
Coral reef	Rich in $CaCO_3$, Antioxidant, Anti-aging, Anti-acne	Skin-care products, Lip-product, Powder, Deodorant
Jelly-fish	Anti-aging, Hydrogel	Skin-care product
Hydra	Anti-oxidant, Emollient	Lip-product, Makeup remover, Skin-care

III. SOME MAJOR FUNCTIONS OF MARINE COSMETICS

Marine resources provide various functional benefits in cosmetic formulations which ultimately are beneficial to human skin. Ingredients from marine sources provide skincare benefits as follows;

1) Moisturizing Properties

The natural moisturizing factor of the skin is mainly comprised of amino acids, which act to maintain cutaneous hydration, thus allowing for normal desquamation and healthy skin. Common treatments of dry skin are topical moisturizers, which contain ingredients to mimic those comprising the NMF, or are formulated to encourage the occlusion or attraction of water into the epidermis.

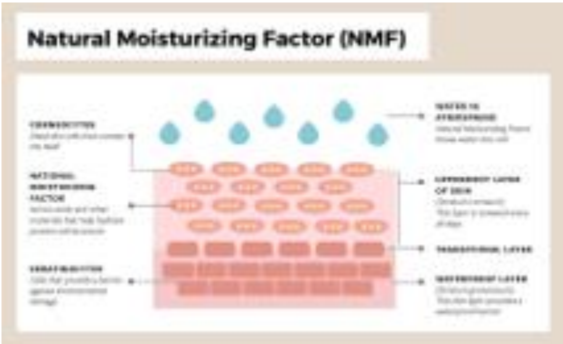

Fig.7 Natural Moisturizing Factors of skin

Fig.8 Red algae

Linoleic-acid acts as a precursor for ceramide lipid molecules, and as an important factor of the Stratum Corneum Permeability Barrier (SCPB). The SCPB reduces both Trans-Epidermal Water Loss (TEWL) and pathogenic invasion.[12] Marine-derived lipids can aid in preserving skin hydration by maintaining the lipid matrix of the SC. Omega-3 oils can be easily extracted from several marine and freshwater fish, which are naturally enriched in Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA). The long-chain EPA and DHA can be obtained only from certain organisms, mainly of aquatic origin, whereas all terrestrial plants produce and contain fairly high amounts of ALA [alpha linoleic acid], which is the precursor to the ω-3 series Fatty Acids (FAs).[13]

The oil of orange roughy (*Hoplostethus atlanticus*), also known as the slime-head and deep-sea perch, has been known to exhibit moisturizing and emollient abilities comparable to that of petroleum-based products. The oil produced is a wax ester composed mainly of fatty alcohols including TAGs and PLs as predominant with palmitic acid, oleic acid, eicosenoic acid, EPA, and DHA, although wax esters constituted their major component and fatty acids which are 70% as efficiently as petrolatum products.[14] The oil of squid (*Loligo loligo*), Extraction from squid indicated that 13±5% of the wet weight of squid was oil, and the oil had 29.40% saturated fatty acids and 23.70% single-band unsaturated fatty acids, and the total value of the unsaturated multiple-band fatty acids of the same was 40.20%. Squids are nowadays considered the new and rich source of Omega-3 and Omega-6 fatty acid[15].

Collagen and collagen hydrolysate are common moisturizing active ingredients with little supporting scientific evidence of their hydrating benefits. Bovine collagen sources are scrutinized due to hygiene concerns, but collagen can be derived from several marine fish, as well as organisms, offering alternative sources, where some marine collagen has shown better biocompatibility. It should however be considered that marine collagen also has weaknesses such as a lower degradation temperature and therefore more limited application than bovine sources. Recently, collagen extracted from the Jellyfish *Nemopilema nomurai* has been proposed to have a significant moisturizing effect.[16] Jellyfish collagen conformed to the characteristics of type I collagen according to amino acid composition and gel electrophoresis analysis. The jellyfish collagen exhibited good solubility under the conditions of pH 3–5[17].

Red algae (*Rhodophyta*) are known as the source of unique sulfated-galactans, such as agar, agarose, and carrageenan. The wide practical uses of these polysaccharides are based on their ability to form strong gels in aqueous solutions.[18] Due to the relatively unexplored biochemical diversity of commercialized bacteria EPS, it offers a promising route to new bioactive molecules with moisturizing or anti-aging actions.

2) Surfactant

Surfactants with diverse properties and low production costs are required to increase the applications of natural Surface-Active Compounds, which gives greater incentive to develop surfactants of biological origin produced by microorganisms. Bio-surfactant (BS) produced from marine bacteria can facilitate hydrocarbon dispersion, degradation, emulsification, and bioavailability. BS from cold-adapted marine microorganisms or psychrophilic organisms can work efficiently at cold and freezing temperatures and are therefore suitable in laundry detergent formulations. The potential uses of BS are further improved by their low toxicity and they can be readily biodegraded. Hence, marine bacteria offer an excellent opportunity for the discovery of new SAC molecules with distinctive properties. Although highly attractive, the biosynthesis of BS from marine organisms has largely been overlooked. The mechanism of their regulation during synthesis is also not fully understood adding further difficulties to the process of their production. Several approaches are required before the widespread application of marine-derived BS such as (i) Isolation and identification of a novel, non-pathogenic marine BS-producing bacteria (ii) Optimization of culture conditions to achieve sufficient yields of BS, and (iii) Characterization of genes involved in BS production from marine organisms. These will allow the use of marine strains in large-scale BS production processes while improving yield and cost-efficiency of BS production.[19]

3) Antioxidants

Antioxidants play an important role in cellular protection against aging by preventing Ultra Violet (UV)-induced Reactive Oxygen Species (ROS) such as superoxide anion, hydroxyl radical $HO^{\cdot}$, and H_2O_2 to attack membrane lipids, proteins, and DNA. Since the oxidation of membrane lipids is one of the most important factors that decrease the youthful appearance of the skin, the prevention of ROS formation is fundamental. Antioxidants protect the pro-oxidative environment to which human skin is exposed, in particular, UV radiation, smoke, and air pollutants. Antioxidants consist of enzymatic and non-enzymatic molecules. Enzymatic antioxidants include superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and glutathione transferase, which are present in human plasma and erythrocytes. Non-enzymatic antioxidants consist of many classes of small molecules such as β-carotene, *R*-tocopherol, ascorbic acid, and ubiquinol among others.

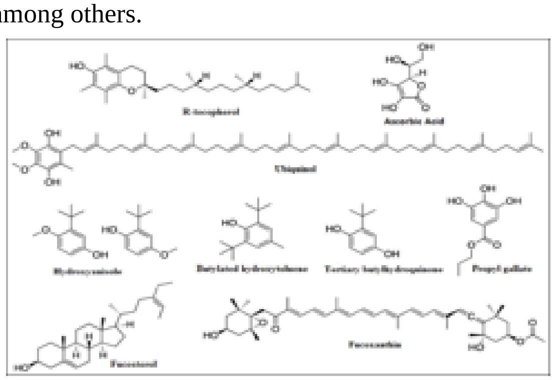

Fig.9 Nonenzymatic antioxidant

Natural pigments such as chlorophylls, carotenoids, and tocopherol derivatives such as vitamin E and isoprenoids are also interesting natural antioxidants obtained from marine resources. The antioxidant and anti-inflammatory properties of carotenoids, which contribute to their photo-protection of the skin through inhibition of UV-A induced ROS toxicity, make them major ingredients in many sunscreen lotions. On the other hand, Mycosporine-like amino acids (MAAs) can not only protect the skin against UV radiation but also exhibit a high antioxidant activity by scavenging superoxide anion, and therefore prevent lipid peroxidation. Another interesting class of natural antioxidants is marine-derived oligosaccharides and peptides. Algae-derived carbohydrates have been suggested to have, besides their thickening and moisturizing properties, antioxidant, anti-melanogenic, and antiaging properties, which are beneficial to the skin, therefore representing value-added cosmeceuticals.[20]

4) Anti-aging

Skin aging refers to the degradation of the dermis, including dryness, enlarged pores, fine lines, and loss of elasticity. A decrease in collagen gene expression, low fibroblast activity, and shrinking of the lamellar barrier also influence aging. The cosmetic industry offers a variety of anti-aging products, which stimulate collagen and glycosaminoglycan synthesis by fibroblasts in the epidermis, thus increasing the firmness and flexibility of the skin's corneal layer.[21] The principle active with anti-aging benefits is carotenoids. β-carotene, the main carotenoid produced by microalga *Dunaliella salina* has an excellent capacity to prevent Reactive Oxygen Species (ROS) formation. It produces more than 10% of β-carotene compared to its dry weight. β-carotene is also used in anti-aging formulations as provitamin-A.[22]

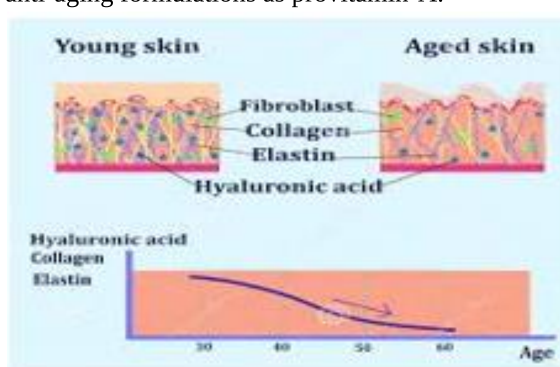

Fig.10 Skin Aging

The other remarkable active used in anti-aging treatment include *Astaxanthin* from *Haematococcus Pluvialis*, having better antioxidant properties than α-tocopherol (Figure. 12).[23] Bacterial polysaccharides are one of the most used bio-active substances for anti-aging. It has emulsifying, absorption, and gel-formation properties. Marine fish-derived collagen has excellent skin-repair properties and is thus widely used in cosmetic formulations.[24] Hyaluronic acid is a major component of skin extracellular matrix. Inducers of hyaluronic acid synthesis are commonly used in anti-aging products. An aqueous extract of the brown alga *Macrocystis pyrifera* stimulates the synthesis of syndecan-4, an important protein of the extracellular matrix. Sea mud helps to retain water, equilibrates skin pH, promotes acne repair and prevention, and also exhibits anti-aging properties. However, due to toxic elements and heavy metals in sea mud, it is subjected to strict control.[25]

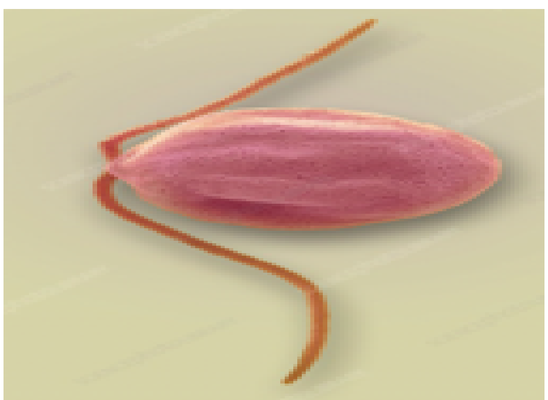

Fig.11 *Dunaliella salina*

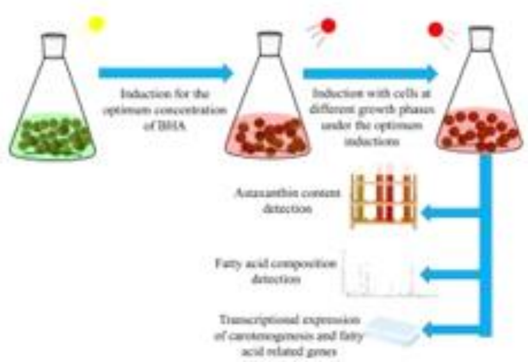

Fig.12 Astaxanthin production from *Haematococcus pluviali*

5) Skin-whitening

The rising issues of hyper-pigmentation, tanning, and lentigo have led to an increase in demand for skin whitening actives in cosmetic products. The skin surface color reflects the pigments it contains, including melanin, melanoid, carotene, oxyhemoglobin, and deoxyhemoglobin. Skin color is also influenced by the thickness and water content of the horny layer, the blood flow, and the amount of oxygen in the blood. Tyrosinase is the key enzyme in melanin synthesis. The inhibition of tyrosinase enzymes leads to skin-whitening effects.[26]

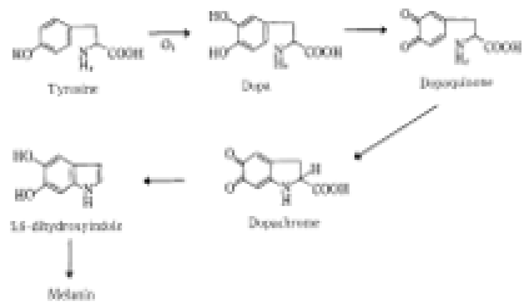

Fig.13 Melanin synthesis pathway

Zeaxanthin obtained in *Nannochloropsis oculata* possesses skin whitening effects. Chlorella extract was found to reduce skin pigmentation by more than 10%. 7-phloroeckol, a phlorotannin derived from *Ecklonia cava* brown seaweed possesses anti-tyrosinase activity.[27] Fucowhite (INCI: Glycerin (and) Water (and) *Ascophyllum Nodosum* Extract) is a whitening active ingredient and is a purified fucoidan-polyphenol complex, extracted from the brown algae, *Ascophyllum nodosum.*[28] Few marine bacteria including *Pseudomonas and Thalassotalea sp* are the tyrosinase inhibitors. Astaxanthin, of the carotenoid's family, also presents effective depigmentation properties. Many skin-whitening actives now find a wide application in cosmetics from terrestrial sources; however, the research continues to find marine sources for skin-whitening action.[29]

Fig.14 *Nannochloropsis oculate*

6) Topical Photo-protection

Human skin can be damaged by chemicals, Ultra Violet (UV) light, and pollution. Continuous exposure to UV radiation leads to skin damage and sunburn which occurs when exposure to UV light exceeds the protective capacity of an individual's melanin. UV-irradiation leads to photo-damage of skin and is characterized by alterations in dermal extracellular matrix composition, which leads to wrinkles, coarseness, mottled pigmentation, and increased epidermal thickness. Photo-aging is also characterized by changes to skin induced by chronic UV-A and UV-B exposure.[30]

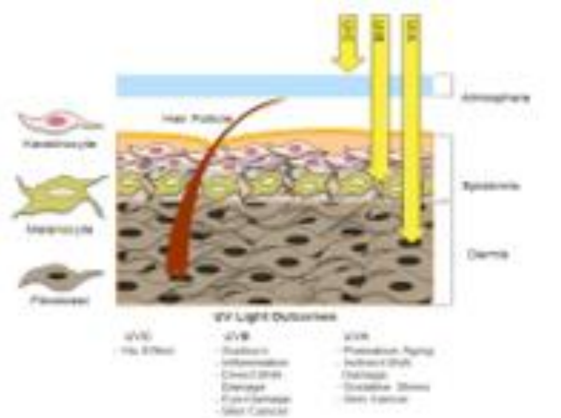

Fig.15 UV light effects on the skin

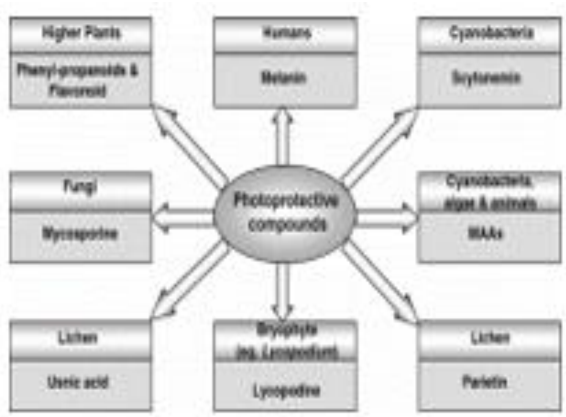

Fig.16 Photoprotective compounds from marine organisms

During the past few decades, a substantial loss in the stratospheric ozone layer has aroused concern about the effects of increased solar UV radiation. An increase in UV-B radiation has led to the need for research on the natural photo-protective compounds from microorganisms, plants, and animals of marine and freshwater ecosystems.

Several marine organisms, such as photosynthetic organisms produce UV-absorbing compounds including Scytonemins (Cyanobacteria), Mycosporine-like amino acids (MAAs), and carotenoids to protect themselves from UV radiations. Mycosporine-like amino acids (MAAs), the ultraviolet absorbable compounds, which are naturally produced by cyanobacteria and algae are biosynthesized by the shikimic acid pathway for the synthesis of aromatic amino acids involved in the protection of aquatic organisms against solar radiation.

Marine algae may be considered a consumer-friendly source of cosmetic products used for photoprotection. Marine algae are rich in sulfated polysaccharides such as carrageenans in red algae, fucoidans in brown algae, and vans in green algae.[31]

IV.ADVANTAGES OF MARINE BIOACTIVES

- They are now becoming popular in skincare as they offer a variety of benefits, more advanced and eco-friendlier.
- They provide vitamins and minerals to the skin, UV and antioxidant protection, anti-aging benefits, and more.
- They have antioxidant properties that have been used in skin-care products to prevent or restore the damage caused by environmental factors, such as UV-rays and low humidity, as well as damage allied with the aging process.
- Marine consequent proteins which can provide equivalents to collagen and gelatin without the associated risks are becoming more popular among consumers because of their abundant health-beneficial effects.
- The anti-oxidant properties help the skin cells in fighting all the free radicals that are produced due to radiation and chemical exposure to the sun.
- Promotes natural skin cleansing by opening pores, restoring shine, and providing rehydration and regeneration of skin cells.
- Most marine bioactive peptides are currently underutilized. While fish and shellfish are possibly the most evident sources of such proteins and peptides, there is also scope for further development of proteins and peptides from the source like algae, sea cucumbers, and mollusks. [32-33]

V.CONCLUSION

As the baby-boomer generation is entering their advanced age, the desire to look younger and healthier has become the global priority. The influence of social media to inform the population and effective dissemination of scientific research have raised the awareness of the risk of using many chemicals in cosmetics. Thus, this millennial is marked by environmentally friendly processes and the use of natural substances. As an alternative to "green technology", marine or "blue-biotechnology" is gaining its turf by providing a myriad of natural products that cannot be found in terrestrial environments and with unprecedented biological and pharmacological properties. Despite some products of a marine origin having already appeared on the market, the number of these products is still very timid when compared to the vastness of the sea and the future discoveries that lie ahead. However, these marine resources are still poorly exploited due to some inherent limitations. The quantity of the compounds isolated from biological materials, which are normally collected from the marine environments, is very small and thus makes it difficult for further bioassays and development. Also, the variations of their products are influenced by environmental changes to which marine organisms are exposed. So, there is a need to find a sustainable way to harvest bioactive metabolites to be used as active ingredients, excipients, and additives. In this aspect, microbial biotechnology can be considered a promising avenue for obtaining a good quantity of high-value compounds. In the context of the blue bio-economy, this translates into financial growth while, at the same time, meeting consumers' demand for ingredients of natural origin and contributing to increased environmental awareness.

VI.ACKNOWLEDGEMENT

Authors are thankful to the Principal, Dr. Deepali Kotwal, and Prof. Dr. Deepak Wasule, Head-Department of Cosmetic Technology, and Teaching faculties of the Department, LAD and Smt. R.P College for women, Nagpur, for providing facilities and sharing their knowledge during the drafting of this article.

REFERENCE

[1] M. Seiji, and Y. Tomita, Handbook of Dermatology, 3B, Structure, and Function of Skin II, Nakayama Shoten,1982, pp. 1-5.

[2] A. Kijjoa, and P. Sawangwong, Drugs and Cosmetics from the Sea, *Marine Drugs*, vol.2, no.2, pp.73–82, June 2004.

[3] A. Mallick, S. Bhattacharya, S. Bhattacharya, and D.S. Baghel. Ayurvedic Drugs from Marine Originates, *IJPRD*, vol.5, no.1, pp.11-20, Mar 2013.

[4] R. Esposito, N. Ruocco, T. Viel, S. Federico, V. Zupo, and M. Costantini, Sponges and Their Symbionts as a Source of Valuable Compounds in Cosmeceutical Field, *Marine drugs*, vol.19, no.8, pp.444, Aug 2021.

[5] L. Uppala, A Review on Active Ingredients from Marine Sources used in Cosmetic, *SOJ Pharm PharmSci*, vol.2, no.3, pp.1-3, Dec 2015.

[6] V. Jesumani, D. Hong, A. Muhammad, P. Pengbing, and H. Nan, Potential Use of Seaweed Bioactive Compounds in Skincare-A Review, *Marine Drugs*, vol.17, no.12, pp.668, Dec 2019.

[7] S. Aishwarya, and P. Meenambika, Sustainable Packaging on the Wish list of Eco-Minded consumers- A Review, *IJREAM*, vol.6, no.10, pp.183-190, Jan 2021.

[8] L.L. Rusoff, and N.R. Mehrhof, A Review on Shark Liver Oil- A Potent Source of Vitamin A for Poultry, *Poultry Science*, vol.18, no.5, pp.339-344, Sep1939.

[9] Y. Zhuang, H. Hou, X. Zhao, Z. Zhang, and B. Li, Effects of Collagen and Collagen Hydrolysate from Jellyfish on Mice Skin Photo Aging Induced by UV Irradiation, *Journal of Food Science*, vol.74, no.6, pp.183-188, Aug 2009.

[10] Z. Lengar, K. Klun, I. Dogsa, A. Rotter, and D. Stopar; Sequestration of Polystyrene Microplastics by Jellyfish Mucus, *Frontiers in Marine Science*, vol.8, pp.690749, Jul 2021.

[11] M. Haq, S. Suraiya, S. Ahmed, and B.S. Chun, A Review on Phospholipids from Marine Source: Extractions and Forthcoming Industrial Applications, Journal of Functional Food, vol.80, pp.104448, May 2021.

[12] B. Quilodran, I. Hinzpeter, E. Hormazabal, A. Quiroz, and C. Shene Docosahexaenoic acid (C22:6n-3, DHA) and Astaxanthin production by Thraustochytriidae sp. AS4-A1 a native

strain with high similitude to Ulkenia sp.: Evaluation of liquid residues from food industry as nutrient sources, *Enzyme and Microbial Technology*, vol.47, no.1-2, pp.24-30, Jul 2010.

[13] C. Minto, and C.P. Nolan, Fecundity and maturity of orange roughy (Hoplostethus atlanticus Collett 1889) on the Porcupine Bank, Northeast Atlantic, *Environmental Biology of Fishes*, vol.77, no.1, pp.39-50, Sep 2006.

[14] C.P. Raya, E. Balguerias M.M. Fernández-Núñez, and G.J. Pierce, On reproduction and age of the squid *Loligo vulgaris* from the Saharan Bank (north-west African coast), *Journal of the Marine Biological Association of the UK*, vol.79, no.1, pp.111-120, Feb 1999.

[15] S. Addad, J. Exposito, C. Faye, S. Ricard-Blum, and C. Lethias, Isolation, characterization and biological evaluation of jellyfish collagen for use in biomedical applications, *Marine Drugs*, vol.9, no.6, pp.967–983, Jun 2011.

[16] D. Bosnakovski, M. Mizuno, G. Kim, S. Takagi, M. Okumura, and T. Fujinaga, Chondrogenic differentiation of bovine bone marrow mesenchymal stem cells (MSCs) in different hydrogels: influence of collagen type II extracellular matrix on MSC chondrogenesis, *Biotechnology and Bioengineering*, vol.93, no.6, pp.1152-1163, Apr 2006.

[17] M. Schwentner, and T.C. Bosch, Revisiting the age, evolutionary history and species level diversity of the genus Hydra (Cnidaria: Hydrozoa), *Molecular Phylogenetics and Evolution*, vol.91, pp.41-55, Oct 2015.

[18] A.I. Usov, Polysaccharides of the red algae. *Advances in carbohydrate chemistry and biochemistry*, vol.65, pp.115-217, Jan 2011.

[19] E. Antoniou, S. Fodelianakis, E. Korkakaki, & N. Kalogerakis, Biosurfactant production from marine hydrocarbon-degrading consortia and pure bacterial strains using crude oil as carbon source. *Frontiers in microbiology*, vol.6, pp.274. Apr 2015.

[20] V. Zutic, B. Cosovic, E. Marcenko, and N. Bihari, Surfactant production by marine phytoplankton, *Marine Chemistry*, vol.10, no.6, pp.505–520, Dec 1981.

[21] O.I. Aruoma. Methodological consideration for characterization for potential antioxidant actions of bioactive components in plants foods, *Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis*, vol.523-524, pp.9-20, Mar 2003.

[22] De Jesus Raposo, M.F. de Morais, R.M. de Morais, A.M. Bernardo de Morais, Health applications of bioactive compounds from marine microalgae, *Life Science*, vol.93, no.15, pp.479-486, Oct 2013.

[23] K. Kushwaha, A. Saini, P. Saraswat, J. Saxena, Colorful World of Microbes: Carotenoids and Their Applications, *Advance in Biology*, vol.2014, pp.1-13, Apr 2014.

[24] P. Sapre, N. Bajpai, and S. Sinha, Astaxanthin: Benefits and Potential Applications in Cosmetics, *WJPPS*, vol.9, no.8, pp.777-791, Jul 2020.

[25] J.B. Guillerme, C. Couteau, and L. Coiffard, Applications for marine resources in cosmetics. *Cosmetics MDPI*, vol.4, no.3, pp.35. Sep 2017.

[26] M. Olaizola, and M.E. Huntley, Recent advances in commercial production of astaxanthin from microalgae. In Recent Advances in Marine Biotechnology, USA, Science Publishers: Enfield, 2003, vol.9, pp.143-164.

[27] A. Alves, E. Sousa, A. Kijjoa, and M. Pinto, Marine-derived compounds with potential use as cosmeceuticals and nutricosmetics, *Molecules*, vol.25, no.11, pp.2536, Jan 2020.

[28] S.Y. Kim, Y.M. Kwon, K.W. Kim, and J.Y.H. Kim, Exploring the potential of Nannochloropsis sp. extract for cosmeceutical applications, *Marine Drugs*, vol.19, no.12, pp.690, Dec 2021.

[29] E.G. Brunt, and J.G. Burgess, The promise of marine molecules as cosmetic active ingredients, *International journal of cosmetic science*, vol.40, no.1, pp.1-15, Feb 2018.

[30] M.S. Fernandes, and S. Kerkar, Microorganisms as a source of tyrosinase inhibitors: a review, *Annals of Microbiology*, vol.67, no.4, pp.343-358, Apr 2017.

[31] R. Pallela, Y. Na-Young, and S.K. Kim, Anti-photoaging and photoprotective compounds derived from marine organisms, *Marine Drugs*, vol.8, no.4, pp.1189-1202, Apr 2010.

[32] S. Lisby, R. Gniadecki, and H.C. Wulf, UV-induced DNA damage in human keratinocytes:

quantitation and correlation with long-term survival, *Experimental Dermatology*, vol.14, no.5, pp.349-355, May 2005.

[33] E.M. Balboa, E. Conde, M.L. Soto, L. Pérez-Armada, and H. Domínguez, (2015). Cosmetics from marine sources, *Springer handbook of marine biotechnology*, Springer, Berlin, Heidelberg, 2015, pp.1015-1042.