INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

Review Article

Thalassocosmetics: Nature's Blueprint for Radiant Skin

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ARTICLE INFO

Published: 23 Aug 2025
Keywords:
Marine Cosmeceuticals, Bioactive Compounds, Skin Hydration, Anti-Aging, Extraction Techniques
DOI:
10.5281/zenodo.16932756

ABSTRACT

Marine cosmeceuticals harness bioactive compounds from oceanic sources such as algae, marine animals, microorganisms, and minerals to offer innovative, natural alternatives in skincare. These marine-derived ingredients— including polysaccharides, peptides, collagen, antioxidants, and minerals—demonstrate multifunctional benefits such as anti-aging, hydration, UV protection, anti-inflammatory effects, pigmentation control, and wound healing. Unique environmental pressures in marine ecosystems have led to structurally distinct and stable compounds, enhancing their therapeutic potential. Extraction methods range from traditional hot-water and acid extraction to advanced technologies like microwave-assisted, ultrasonic-assisted, and supercritical fluid extraction, optimizing yield and bioactivity while maintaining sustainability. In vivo and in vitro studies validate the efficacy and safety of these compounds, employing assays for antioxidant activity, collagen synthesis, skin hydration, and enzymatic inhibition relevant to cosmetic applications. Despite challenges including allergenicity, chemical instability, and environmental concerns, marine cosmeceuticals provide eco-friendly, biologically compatible, and potent ingredients. The expanding global market is driven by consumer preference for sustainable and scientifically supported products, with Asia-Pacific leading growth. Continued research and technological innovation will further integrate marine bioactives into dermatological and cosmetic formulations, balancing nature and science to advance skin health and beauty.

INTRODUCTION

Marine cosmeceuticals are a growing segment in the skincare and cosmetic industry, focusing on natural, sustainable alternatives to synthetic ingredients. These products, derived from marine organisms like algae, seaweeds, sponges, and bacteria, contain bioactive compounds like polysaccharides, peptides, enzymes, and essential fatty acids. These compounds have antioxidant, anti-aging, anti-inflammatory, UV-protective, and skin-repairing properties. The unique

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

environmental conditions of marine ecosystems have led to the development of structurally distinct and highly stable compounds, many of which remain unexplored. These bioactives support biological functions like cellular defense, regeneration, and protection against environmental stressors, making them ideal for cosmetic applications like hydration, collagen synthesis, and skin barrier repair. This project explores the scientific basis, functional benefits, and formulation potential of marine bioactives in cosmeceuticals.

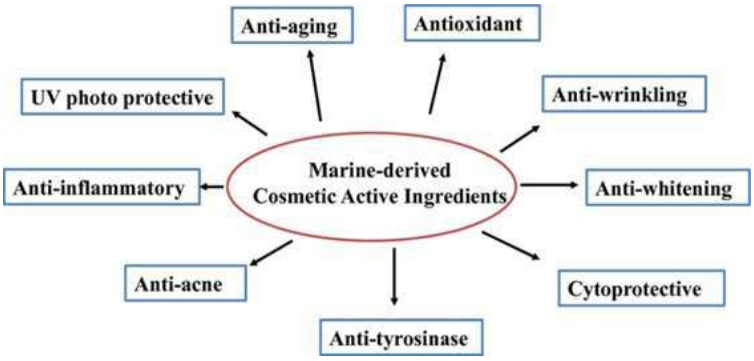

Fig1.1 cosmetic benefits of marine agents

The global marine cosmetics market is expected to grow at a CAGR of 6.4%, with a projected value of USD 9.71 billion in 2023. The market is driven by natural and sustainable ingredients like seaweed, algae, and fish oils, which offer benefits like anti-aging, anti-inflammatory, and skin hydration. Consumer preferences are also driving the growth of marine-based skincare products. Technological advancements in green extraction technologies and marine biotechnology are enhancing the efficacy and sustainability of marine-based ingredients. The Asia-Pacific region is leading the demand, driven by a booming wellness industry and increased awareness of marine health products. Ideal marine ingredients should exhibit beneficial biological effects, be biocompatible and non-toxic, have chemical stability, penetrate the skin, have suitable solubility, be sustainable, and be easily incorporated into cosmetic formulations without negative reactions.

Advantages:

- Provide advanced skin care benefits with scientifically and eco-friendly ingredients.
- Provide vitamins, minerals, UV and antioxidant protection, and anti-aging benefits.
- Sea water contains the body's ideal balance of minerals.
- Marine ingredients have antioxidant properties that prevent or restore environmental damage and aging.
- Marine proteins provide equivalents to collagen and gelatin.
- Marine bioactive peptides are underutilized.
- Marine ingredients have anti-oxidant properties and help restore skin cell hydration.

Disadvantages:

- Some marine extracts can cause allergic reactions.
- Overharvesting marine resources can lead to marine ecosystem damage.
- Marine-derived compounds are chemically unstable and require advanced formulation techniques.
- High cost and limited clinical evidence raise concerns about purity, safety, and long-term health effects.

Marine Skin Care Applications

- **Anti-Aging and Wrinkle Reduction:** Marine peptides, collagen, and polysaccharides stimulate collagen synthesis, improve skin elasticity, and reduce fine lines and wrinkles.
- **Skin Hydration and Moisturization:** Marine-derived humectants like alginate, fucoidan, and hyaluronic acid analogs enhance skin barrier.
- **Antioxidant Protection:** Marine ingredients rich in antioxidants like carotenoids protect skin from free radical damage and environmental stress.
- **UV Protection and Repair:** Certain marine compounds provide natural photoprotection or help repair UV-induced damage.
- **Skin Brightening and Pigmentation Control:** Some marine extracts inhibit melanin production, reducing hyperpigmentation and dark spots.
- **Anti-Inflammatory and Soothing Effects:** Marine bioactives calm irritated skin and reduce redness and inflammation.
- **Wound Healing and Skin Regeneration:** Marine-derived compounds promote wound healing and tissue repair.

Classification of marine cosmeceutical based on their source

1) Marine Algae

1.1)Brown Algae (Phaeophyceae)

Fig 2. Brown algae

1.1a) *Laminaria japonica* and *Laminaria saccharina*

Laminaria japonica and Laminariasaccharina are sulphated polysaccharides used in cosmetics for their anti-aging, anti-inflammatory, and anti-melanogenic properties. Fucoidan enhances collagen synthesis and protects against UVB radiation. Fucoxanthin is an antioxidant with photoprotective properties and reduces melanin synthesis, mitigating hyperpigmentation. Laminarin aids wound healing and photoprotection. Ecklonia cava, another brown algae species, contains phlorotannins like eckol, which have antioxidant, anti-inflammatory, and melanogenesis-inhibitory properties, reducing oxidative stress, attenuating skin irritation, and normalizing pigmentation, highlighting its therapeutic potential in cosmeceutical applications.

1.2) Red Algae (Rhodophyceae)

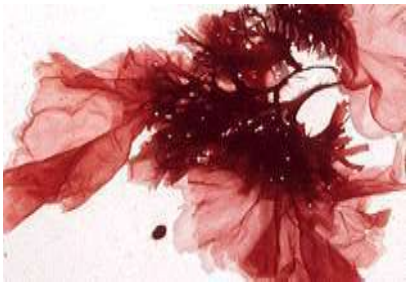

Fig 3. polyphyera spp.

Porphyra spp. and Chondrus crispus are sulphated polysaccharides with multifunctional applications in cosmetic formulations. Carrageenan and porphyran are key constituents, acting as natural hydrogels and rheology modifiers. They contribute to product stability, texture, moisturizing, antioxidant activities, and skin barrier integrity. They also have antimicrobial and anti-whitening properties, making them useful for formulations targeting uneven skin tone and acne-prone conditions. Eucheuma spp., rich in compounds like kappa, iota, and lambda carrageenan, is used

as a gelling or thickening agent in various formulations. These compounds provide smooth texture, viscosity, excellent hydration, anti-aging, antioxidant, and barrier boosting properties.

1.3) Green Algae (Chlorophyceae)

Fig4. ulva spp.

Ulva spp., a type of green algae, contains active components like sulphated polysaccharides, proteins, sterols, and minerals that help maintain skin texture and protect against UV damage. Microalgae like Spruculina and Chlorella contain antioxidants like Astaxanthin, which is used in anti-aging cosmetics to protect the skin from oxidative stress and UV damage. Phycobiliproteins like phycocyanin, obtained from blue-green algae, are used in creams and skincare products as natural dyes, providing antioxidant properties and skin protection.

2) Marine animals

2.1)Fish & marine vertebrates

Fig 5. salmon fish

Fish, such as salmon and cod, are rich in protein, calcium, and minerals, including marine collagen. They also contain Omega-3 fatty acids, which strengthen the skin barrier and reduce inflammation. Fish-derived products are used to enhance skin elasticity, reduce fine lines, and wrinkles. Jellyfish Mucin, rich in collagen-like glycoproteins, provides deep hydration and moisture barrier reinforcement, improving skin bounce, firmness, and overall appearance.

2.2) Molluscs & Shellfish

Fig 6. oyster shell with pearl

Korean skincare products include snail mucin, oyster pearl powder, and oyster shells. Snail mucin, containing hyaluronic acid, glycolic acid, peptides, and allantoin, helps in hydration**,** wrinkle reduction, collagen synthesis, healing, scar fade, and soothing irritated skin. Oyster pearl powder, containing calcium carbonate, conchiolin protein, amino acids, and trace minerals, is used for brightening, anti-pigmentation, and skin tone enhancement.

2.3) Crustaceans

Chitosan obtained from shells of crustaceans is a Cationic polysaccharide with film-forming, antimicrobial, and moisturizing properties it enhances skin repair and locks in mositure

Astaxanthin is also a derivative having Potent antioxidant carotenoid with UV-protective, anti-inflammatory and anti-wrinkle action used for its anti-aging properties.

3) Marine microganism

3.1) Marine Bacteria

Alteromonas macleodii contains exopolysaccharides that provide deep hydration and anti-inflammatory benefits, soothing sensitive skin, and promoting skin repair. Pseudo alteromonas ferment extract stimulates collagen production and elastin, improving skin texture and reducing fine lines. Vibrio alginolyticus soothes irritated skin and protects against chemical, mechanical, and UV stress.

3.2) Marine Fungi & Actinomycetes

Fig 7. marine fungi

Streptomyces sp. and marine-derived Penicillium sp. are two valuable ingredients in cosmeceutical formulations. Streptomyces species contain secondary metabolites like hyaluronic acid and anti-aging peptides, which improve skin moisture retention, elasticity, and antimicrobial benefits. Marine-derived Penicillium species produce bioactive compounds like marine enzymes, peptides, and antioxidant metabolites, which promote skin detoxification, reduce stress, and enhance cell renewal, contributing to healthier, more resilient skin.

4) Marine Mineral and Water

Marine thermal spring water, a nutrient-rich marine ingredient, is known for its soothing properties, which help calm sensitive or irritated skin, restore its natural pH balance, and strengthen its protective barrier. It is also known for its antioxidant benefits, protecting the skin against environmental stressors. Seawater, a nutrient-rich marine ingredient, contains over 90 ionic minerals, revitalizing skin cells, enhancing microcirculation, and improving overall hydration. It detoxifies and oxygenates the skin, making it look fresher and more vibrant. Marine magnesium, found in forms like magnesium chloride and sulfate, is known for its calming and anti-inflammatory effects, supporting the healing process and improving skin resilience. AHAVA's Dead Sea Magnesium Body Lotion combines marine magnesium with Dead Sea minerals to deeply hydrate and soothe dry skin. Marine trace element complexes, featuring essential nutrients like zinc, copper, manganese, selenium, and silicon, provide cosmetic benefits, regulating sebum production, fighting free radicals, and supporting enzymatic functions vital for collagen production. These elements contribute to a healthier skin, making them a popular choice for sensitive skin care routines.

Extraction techniques of marine derivatives

1. Extraction of marine algae

1.a) Hot-Water Extraction

Hot water extraction is a widely used method for isolating intracellular compounds from algae by disrupting the cell wall. As described by Chi et al., algae samples were first washed with distilled water, dried at 60°C, and ground into a fine powder (<0.5 mm). This powder was then soaked in hot water (100°C) for 3 hours with continuous stirring. The extract was cooled, centrifuged, and the supernatant was precipitated using 95% ethanol at 4°C for 24 hours. The resulting precipitate was dried at room temperature overnight to yield crude polysaccharides, which were further purified by the Sevag method for deproteinization. To isolate specific polysaccharide fractions, Cho et al. dissolved 100 mg of crude polysaccharide in distilled water and applied it to a DEAE Sepharose fast flow column for ion-exchange chromatography. Elution was

performed using distilled water and NaCl. Reported yields vary (10%–25.1%) due to differences in extraction parameters and solvent concentrations during fractionation.

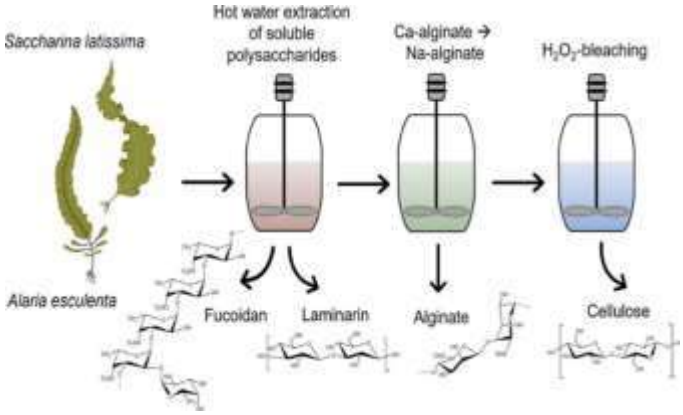

Fig 8. Hot water extraction of marine algae

1.b) Extraction of Fucoidan

Three hundred grams of dried algae were soaked in 7000 mL water for 24 hours, then filtered to obtain a clear extract. To 300 mL portions, 1% chitosan, HACC, or CPAB was added until complex formation stopped. After standing for 2–8 hours, precipitates were centrifuged, freeze-dried, and weighed. Each 0.1 g sample was suspended in different NaCl, KCl, or HCl (pH 2) solutions, stirred for 10 hours, and centrifuged. Supernatants were adjusted to 100 mL, and fucoidan content was measured to assess separation efficiency.

2. Extraction From Marine Animals

2.a) Extraction of Collagen from Jellyfish

Acid extraction is the most commonly used, mainly for fish by-products, jellyfish. The method starts by washing the raw material with distilled water, cut into small pieces, and chemically treated with sodium hydroxide (NaOH) to remove non-collagenous proteins. In some cases, additional extra steps are essential, such as fat removal required for collagen extraction from codfish swim bladders or even the demineralization/ decalcification that is required for the isolation of collagen from scales, cartilage, or bone.Later, collagen isolation was achieved using an acetic acid solution, followed by centrifugation. Finally, the remaining biomass can be re-extracted following the same procedure. Furthermore, the collagen was precipitated by the addition of sodium chloride (NaCl) is separated by centrifugation, purified by dialysis, and finally lyophilized . The extraction methods to obtain collagen using acidic methodology

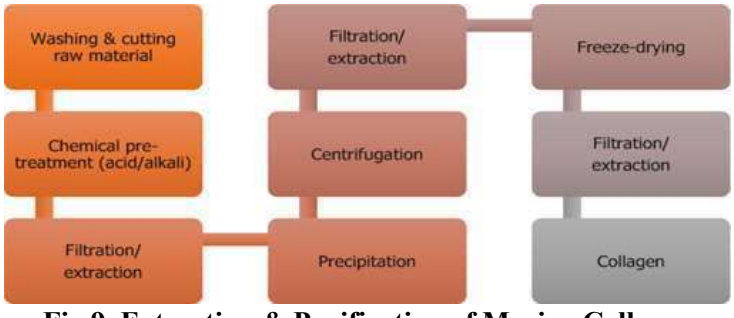

Fig 9. Extraction & Purification of Marine Collagen

2.b) Extraction of Chitin from Crab Shell

Mud crab shell waste was processed to extract chitin through deproteinization, demineralization, and decolouration. In the first step, the shells were treated with 4% NaOH (1:20 w/v) at 90°C for 2 hours, then washed to neutral pH and dried at 60°C for 24 hours. The deproteinized shells were then demineralized using 2.5% HCl under similar conditions for 6 hours. After washing and drying, the samples underwent decolouration with acetone for 10 minutes and were air-dried, followed by final washing and oven-drying at 60°C for 24 hours. This yielded deproteinized, demineralized, and decolourized chitin from mud crab shells.

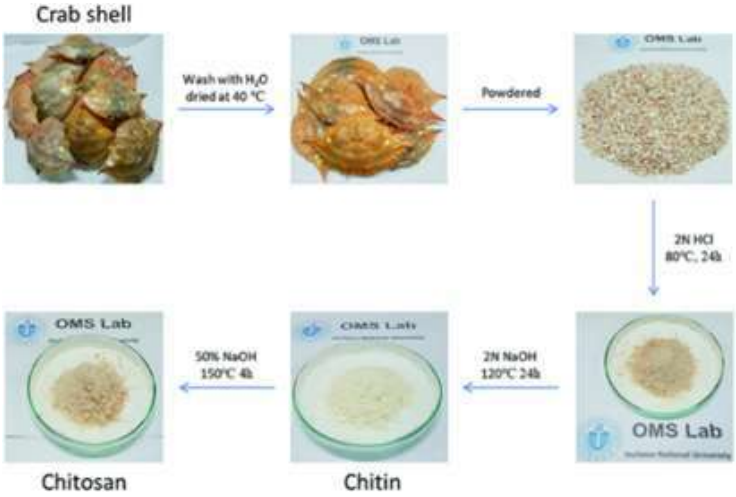

Fig10. Extraction of Chitin from Crab Shell

3. Extraction from Marine Microorganism

3.a) Extraction of Exopolysaccharide from Marine Bacteria

A culture of Altramons macleodii is first incubated under optimal conditions, then mixed with sterile distilled water (2:1 ratio) and blended to distribute mycelia. The pH is adjusted to 7.0 using 0.1 N NaOH. The mixture is heated at 80°C for 30 minutes to deactivate enzymes. A portion is centrifuged, and the supernatant is mixed with ethanol (1:1) and stored at 4°C for 12 hours to precipitate extracellular polysaccharides (EPS). Biomass and EPS are dried and weighed. For purification, the culture is filtered, re-centrifuged, reprecipitated with ethanol, sieved, washed, frozen at –85°C, freeze-dried, and weighed to determine EPS yield.

3.b) Microwave-Assisted Extraction (MAE)

MAE improves the heat and mass transfer performance of the extraction process by using the characteristics of microwave. It is easy for selection, save the operation time, the solvent consumption low, and the yield is high with effective ingredients, which is widely used for extraction of marine bio active compounds For example MAE is method to separate and extract chitinase from the fungus *Rhizopusoryzae* , with a high final chitinase yield.

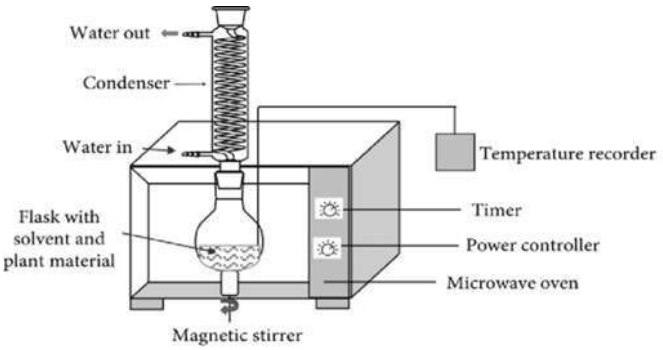

Fig:11. Microwave Extracter

3.c) Supercritical fluid extraction (SFE)

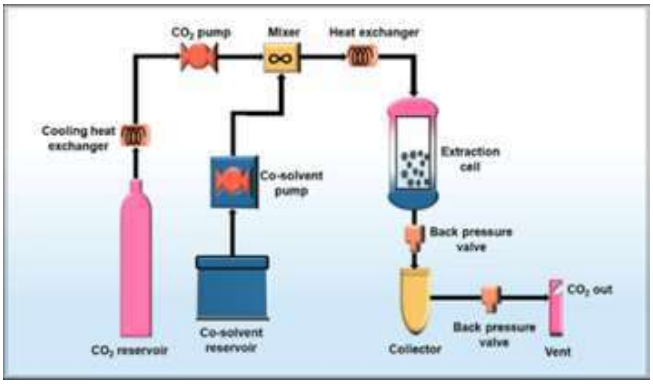

Fig:12. Super Critical Fluid Extracter

It is a clean and efficient method widely used for the extraction of fat-soluble compounds such as fatty acids , carotenoids and other bio active molecules from marine microorganism particularly microalgae and cyanobacteria

The process typically uses carbon dioxide (CO_2) as the main solvent due to its non-toxic, non-flammable, and environmentally friendly nature. When CO_2 is brought to a supercritical state—meaning it is held at a temperature and pressure above its critical point—it exhibits unique properties that allow it to diffuse through solids like a gas and dissolve substances like a liquid.

In SFE, dried and finely ground marine biomass is packed into an extraction vessel. Supercritical CO_2 is then passed through the biomass, selectively dissolving lipophilic compounds. Sometimes, a small amount of a co-solvent such as ethanol is added to enhance the extraction of more polar molecules like pigments or certain antioxidants. Once the extraction is complete, the pressure is reduced, causing the CO_2 to revert to its gaseous state and leaving behind a purified extract.

One of the key advantages of SFE is that it leaves no harmful solvent residues, making it especially suitable for food, pharmaceutical, and cosmetic applications. The method also operates at relatively low temperatures, preserving the integrity and bioactivity of heat-sensitive marine compounds. Overall, SFE is a highly selective, eco-friendly, and efficient method for isolating valuable natural products from marine microorganisms.

3.d) Ultrasonic assisted extraction(UAE)

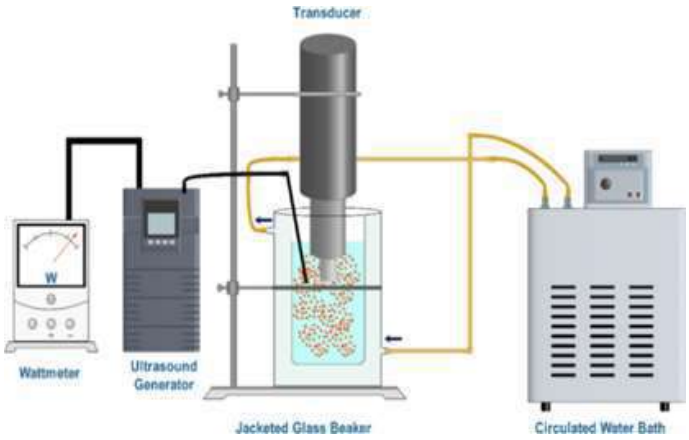

Fig 13. Ultra Sonic Assisted Extracter

Ultrasonic-Assisted Extraction (UAE) is a modern and efficient technique used to extract valuable intracellular compounds from marine microorganisms such as microalgae, bacteria, and fungi. This method uses ultrasonic waves—essentially high-frequency sound waves—to break open the tough cell walls of microorganisms. The energy from the ultrasound creates microscopic bubbles in the liquid that rapidly collapse, generating intense local pressure and heat. This phenomenon, known as cavitation, physically disrupts the cells and allows solvents to penetrate more easily and extract the desired compounds.

UAE is especially useful when working with compounds that are trapped inside thick or resistant cell walls, which are common in marine microalgae and cyanobacteria. By making it easier for the solvent to reach these compounds, UAE significantly boosts extraction efficiency and yield. It's often used in combination with traditional solvent or water-based extraction methods to enhance the overall process.

The method is relatively quick, uses less solvent, and operates at lower temperatures, which helps protect heat-sensitive compounds like pigments, antioxidants, and fatty acids. This makes UAE an attractive option for obtaining bioactive ingredients for use in nutraceuticals, cosmetics, and pharmaceuticals. Overall, Ultrasonic-Assisted Extraction is a powerful, gentle, and environmentally friendly approach to unlocking the potential of marine microorganisms.

4.) extraction of marine minerals

4.a) Extraction of minerals

Precipitation is the most common method for recovering magnesium from reject brines, using agents like NaOH, NH_4OH, Na_3PO_4, and $Ca(OH)_2$. Industrially, calcined dolomite, burnt lime, or ammonia are preferred to form $Mg(OH)_2$. However, calcium-based reagents can cause excess sludge and unwanted calcium salt precipitation, limiting $Mg(OH)_2$ quality. Ammonia introduces ammonium ions, which may form explosive nitrogen trichloride during electrolysis. NaOH causes poor filtration and slow sedimentation. Studies show that reagent type, contact time, and conditions influence $Mg(OH)_2$ crystal size. Less stirring, low temperatures, and concentrated precipitant improve crystal growth, sedimentation, and filtration efficiency during magnesium recovery.

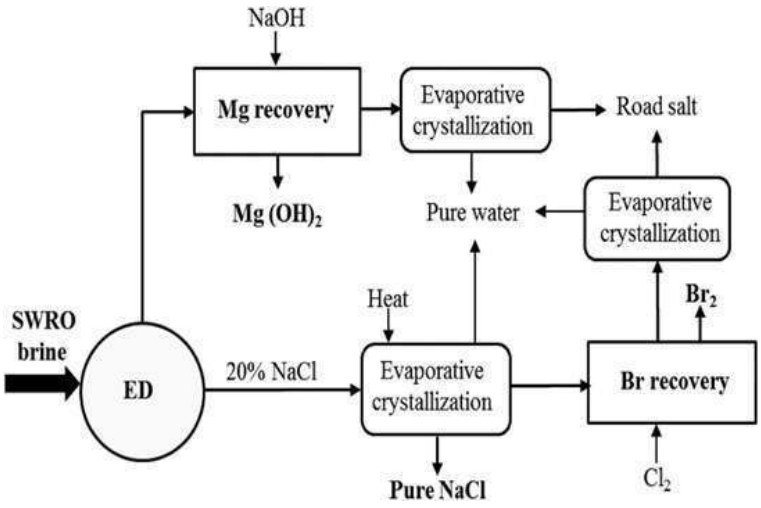

Fig 14. Extraction of Marine Minerals using Evaporation Crystallisation Method

4.b) Membrane distillation crystallisation (MDC)

Membrane Distillation Crystallization (MDC) is a sophisticated method for the recovery of minerals from seawater brines. MDC employs membrane distillation (MD), in which a hydrophobic microporous membrane is used to demarcate the distilled water from the brine solution. The hydrophobic nature of the polymeric membrane keeps the water from passing through the pores, developing a vapour-liquid interface at the pore entrance. On the hot side (retentate), water evaporates, travels through the membrane, and condenses on the chilled side (distillate). In MDC, a hydrophobic hollow fiber membrane module is employed to provide fine control of supersaturation of salts, with crystallization taking place in a circulating crystallizer and recovery in a system to avoid salt build-up within the MDC unit. The process causes supersaturation and results in a metastable solution in which crystallization, comprised of nucleation and growth, occurs. MDC is a great method of brine concentration because it has very controlled levels of supersaturation. It also produces crystals of higher quality than do other solid separation operations like cooling or evaporative crystallization.

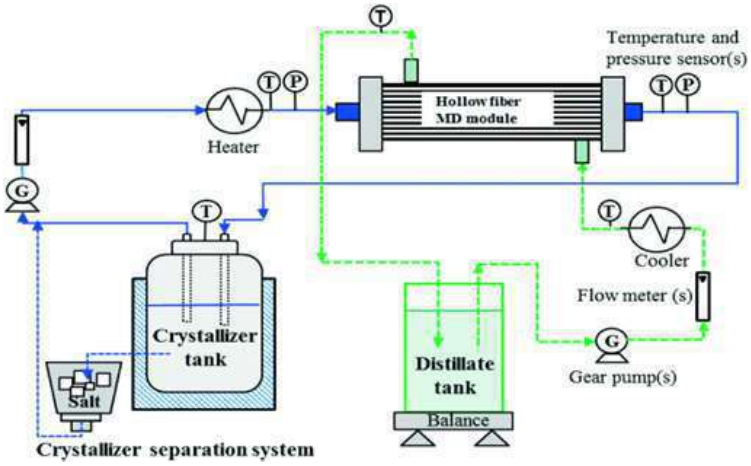

Fig 15. :Membrane Distillation Apparatus

4.c) Deep sea mining

Deep-sea mining is an advanced process used to harvest valuable minerals from the ocean floor,

often at depths of several thousand meters. It starts with exploration, where scientists use sonar mapping and underwater drones to locate areas rich in mineral deposits like polymetallic nodules, which contain metals such as cobalt, nickel, manganese, and copper. Once a suitable site is identified, remotely operated vehicles (ROVs) or robotic collectors are sent down to the seabed. These machines gently scoop or vacuum up the mineral-rich nodules scattered across the ocean floor. The collected material is then transported to the surface through long pipes or containers aboard specialized ships. Back on the ship or later at land-based facilities, the rocks undergo crushing and chemical processing to extract the valuable metals. While deep-sea mining holds great promise for providing essential materials used in technology and renewable energy, it is still a developing field. Scientists and environmentalists closely study the potential impacts on fragile marine ecosystems to find ways to minimize harm, making it a delicate balance between resource extraction and ocean conservation.

4.d) Aqua element extraction

The Aqua Mineral Extraction process starts by collecting large volumes of seawater, usually from clean coastal areas or specially designed intake systems. The seawater is then passed through filtration to remove any debris or impurities. Next, the water undergoes treatment where specific chemicals are added to cause the dissolved minerals—like magnesium, calcium, or potassium—to form solid particles that can be separated out. Sometimes, techniques like evaporation or ion-exchange are used to concentrate these minerals even further. After the minerals settle or are filtered out, they are collected as a concentrated mineral product. Finally, the purified water can be returned safely back to the sea or further treated for other uses. This method allows us to gently and sustainably harvest valuable minerals directly from the ocean without harming marine life.

In vivo studies

In vivo testing evaluates marine active compounds' biological activity and efficacy in living organisms, providing insights into their behavior in a complex system, potential toxicity, and therapeutic effects, complementing in vitro studies.

IMPORTANCE IF INVIVO TESTING

- Provides realistic biological response for drug activity identification.
- Reduces clinical trials for safety testing.
- Conducts toxicity studies for drug safety assurance.
- Facilitates disease modeling for understanding disease progression in living systems.
- Crucial for drug development, testing absorption, metabolism, and excretion in the body.

a) Amino Acid Profile

The characterization of marine collagen can be done by using the amino acid profile of the extract, After extraction, both origin collagens were hydrolyzed and separated through a cation-exchange resin column accordingly standard procedure, the column eluent used was ninhydrin reagent and then they are analyzed using 440nm and 540nm The quantitative analysis was carried out using Norleucine as an internal standard. The represented results correspond to a mean of three independent measurements.

b) Carbon Clearance Assay Fuciodan

The carbon clearance test . Briefly, after 24 h following the last administration of fucoidan, the 4-times diluted India ink as intravenously injected into each mouse (4 groups, n = 10) at the dose of 100 µl/10 g body weight. At 2 min (t1) and 10 min (t2) after the intravenous injection, 20 µl of orbit blood was collected using a capillary pipette and immediately mixed with 2 ml 0.1% Na_2CO_3 solution.

c) Wound Healing Model

In vivo wound healing studies use excision/incision models in rodents to assess re-epithelialization, collagen deposition, and tissue regeneration. Marine collagen, chitin, and algal polysaccharides accelerate healing by promoting fibroblast proliferation and neovascularization. For example, fish-derived collagen gel enhanced wound closure and collagen fiber density in diabetic rat models.

d) Antioxidant Assay

Antioxidant efficacy is evaluated by measuring oxidative stress biomarkers (e.g., MDA, SOD, GSH) in skin tissue post-treatment. Marine antioxidants like astaxanthin or fucoidan protect against UV-induced oxidative damage. In vivo, astaxanthin-rich microalgae extract reduced MDA levels and enhanced SOD activity in UVB-exposed mouse skin, confirming their protective action.

e) Corneometry (Hydration Test)

This method measures the corneum's hydration by detecting capacitance changes of the skin . It is used evaluate moisturizing effects of topical agents like marine hyaluronic acid or collagen peptides. An Increase incorneometric values post-application indicates an increase hydration. For example, marine-derived HA significantly improved skin hydration in UV-damaged murine models.

Fig 16. Corneometer

INVITRO STUDIES

In vitro studies involve testing marine-derived cosmetic compounds on cultured cells or tissues under controlled lab conditions. These methods help assess biological activity, safety, and efficacy before in vivo or clinical testing.

IMPORTANCE IF INVIVO TESTING

- **To avail realistic biological response:** invivo testing allows researchers to identify activity of a drug in real biological conditions instead of lab testing
- **In safety testing :** to perform safety testing of a drug by reducing less clinical trials
- **Toxicology studies**:to perform the toxicity studies to ensure the safety of the drug
- **Disease Modeling**: They allow researchers to study how diseases develop and progress in a living system, which is crucial for finding treatments.
- **Drug Development**: These studies are a key step in testing new drugs for how they are absorbed, metabolized, and excreted by the body.

a) Scanning Electron Microscopy (SEM)

SEM provides high-resolution surface imaging to analyse the morphology of marine-derived

compounds like chitin or collagen. It reveals structural features such as porosity, Fiber alignment, and particle distribution, which influence the formulation, texture, and bioactivity of cosmetic products, especially in wound dressings, hydrogels, and delivery matrices.

Fig 17. Scanning Electron Microscope

b) Fourier Transform Infrared Spectroscopy (FTIR)

FTIR detects functional groups in marine biopolymers by measuring infrared absorption of molecular vibrations. It is used to confirm chemical structure, purity, and formulation compatibility of cosmetic actives like collagen, hyaluronic acid, or algal polysaccharides, aiding in stability assessments and formulation development of creams, gels, and serums.

Fig 18. Fourier Transform Infrared Spectroscopy

c) X-Ray Diffraction (XRD)

XRD analyses the crystalline structure of marine compounds such as collagen or chitosan. It differentiates between amorphous and crystalline phases, influencing solubility, bioavailability, and texture in cosmetic formulations. XRD is essential for optimizing marine ingredient functionality in powders, films, and encapsulated delivery systems for skincare products.

d) Tyrosinase Inhibition Assay (Whitening Activity)

This assay determines the ability of marine compounds to inhibit tyrosinase, a key enzyme in melanin biosynthesis. Extracts like fucoxanthin or kojic acid from marine fungi are tested in vitro. Reduced dopachrome formation indicates skin-lightening potential, making this method essential for evaluating anti-pigmentation efficacy in cosmetic formulations.

CONCLUSION

The study explores marine cosmeceuticals, a promising source of bioactive compounds for skin care and dermatology. Marine-derived ingredients, such as collagen, hyaluronic acid, chitosan, alginates, fucoidan, peptides, and antioxidants, offer various cosmetic benefits and therapeutic effects, including hydrating, anti-aging, anti-inflammatory, photoprotection, and wound healing. These products are superior to synthetic ingredients due to their biochemical properties, extraction methods, and mechanisms. They are also environmentally sustainable. Laboratory-based methods, such as SEM, FTIR, and X-ray diffraction, can advance drug evaluation to establish the stability, safety, and efficacy of marine-based materials in cosmetic formulations. The marine domain of cosmeceuticals offers an ethical and environmentally-conscious alternative to synthetic ingredients. Further research in marine biological, pharmacology, and cosmetic science will expand our understanding of marine cosmeceuticals and support new skin care pathways that balance nature and science.

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HOW TO CITE: Dr. Raslamol K., Remya Binu, Faris Ali Nuwaizer T. F., Fathima Asna P. A, Mohamed Minhaj, Nihala Thasneem K. S., Rizwan Ahmed A. A., Thalassocosmetics: Nature's Blueprint for Radiant Skin, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 8, 2509-2522. https://doi.org/10.5281/zenodo.16932756