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The Application of Nanotechnology in Natural Cosmeceuticals

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Abstract. With the continuous improvement of people's economic level and the maturity of consumption concepts, natural cosmeceuticals (with therapeutic effects) have received more and more attention, which has prompted the innovative development of the cosmeceuticals industry. Natural ingredients derived from plants and the marine have attracted the attention of scientists for their sustainability and less skin irritation. These ingredients, along with low skin penetration and instability, influence formulation development. Nanotechnology is used to help improve the shortcomings of natural ingredients such as instability in formulations. However, the toxicity of nanotechnology and regulatory gaps have also raised concerns and potential concerns among consumers. This paper provides an overview of potential active ingredients in botanical and marine cosmeceuticals and how they can improve formulation innovation under the action of different nano delivery systems. Relevant literature from pub med, web of science, and other websites are studied to corroborate the most recent trends in the development of cosmeceuticals and the most recent advancements in industry regulation. As a result, a key area of research for scientists continues to be how to enhance formulations while creating natural nano-cosmeceuticals to allay consumers' worries about toxicity.

1. Introduction

Cosmeceuticals are a class of cosmetic preparations used to provide aesthetic effects and to treat skin conditions due to their active ingredients providing both cosmetic and therapeutic effects.[1] With the advent of Covid-19, there are an increasing number of consumers are turning to natural products to maintain their health, and they believe that healthy skin can withstand environmental stressors.[2] This drives the cosmeceutical industry to constantly look for new natural ingredients for formulation. There are many articles proving that plant-derived active ingredients are favored by scientists for their unique effects, and they have successfully used nanotechnology to address the attendant limitations of low skin penetration, low solubility, etc. [1, 3, 4, 5] Nevertheless, the few studies that have shown that active ingredients derived from the marine still have a huge space for exploration, especially as a component of cosmeceuticals and nanocarriers.

Therefore, this paper primarily summarises the practical applications of different nano delivery systems in the development of plant-derived cosmeceuticals, potential active ingredients originating from the ocean and their benefits, as well as the toxicity of nanocarriers and industry regulatory loopholes, in order to anticipate the future development trend of cosmeceuticals and provide new research and development ideas for cosmeceutical companies.

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2. phytocompounds-based cosmeceuticals

Epicatechins, catechins, curcumin, hydroxylbenzoic, gallic acids and cinnamic acids, quercetin, ascorbic acids, luteolin, alpha and beta carotene, complex polysaccharides, and fatty acids are some of the phytobioactive compounds found in cosmeceuticals.[5] Because these active substances are derived from natural sources, they lack the artificial properties of synthetic chemical ingredients, which are usually implicated in adverse effects such as skin irritation.[1] Phytocompounds on the other hand, have drawbacks that cannot be overlooked, such as low bioavailability, low solubility and stability, and low skin permeation rate. The use of nanotechnology to combine phytocompounds is seen as a novel way to address the compounds' limitations. Many studies have shown that nanoformulations containing nano-size phytocompounds have better features, the most prominent of which is that they prevent the physical and chemical degradation of active ingredients, improve their efficacy and transport of active ingredients to the skin, and enhance the tolerance of UV filters. [4]]At the same time, there have been significant improvements in targeted administration, controlled release, and improved phytocomponents loading capacity in a smaller amount.[4]

2.1. Vesicular systems

Liposomes are globular, biodegradable vesicles made of bilayers of phospholipids and cholesterol. Typically, the size of a liposome varies from 20 nanometers to a few hundred micrometres. [6] Due to the amphiphilic nature of phospholipids, both hydrophilic and hydrophobic ingredients can be embedded in liposome polar and oil-soluble cavities, respectively, to release the active ingredient in a controlled manner. [1] Liposomes are used in a range of cosmeceuticals because they encapsulate active moiety readily and are biocompatible, biodegradable, and nontoxic. [6] Sensitive vitamins, for instance, can be encapsulated in liposomes to protect them from light and temperature deterioration and improve their effectiveness as anti-aging active ingredients. [8]Gel-state phospholipids are usually selected to ensure good stability of liposome structures and active ingredients in cosmeceuticals. [4]

Pinsuwan et al. investigated the viability of liposomes as transdermal delivery vehicles for Labisia pumilla and ficus deltoidea. In rat skin permeation tests, liposomes encapsulating F. deltoidea and L. pumila demonstrated superior transdermal penetration compared to unencapsulated extracts. [1]

Chitosan-coated liposomes were created by Phetdee et al. as a delivery vehicle for native AHA derived from tamarind pulp and determined the physical properties, and encapsulation efficiency of AHA in chitosan-coated liposomes and release curves. The results showed that the release of tartaric acid from liposomes encapsulated by chitosan was prolonged, while the release of tartaric acid from tamarind extract was very fast. At the same time, the release rate becomes delayed as the quantity of chitosan coating increases. Additionally, they discovered that the liposomes' chitosan covering could improve the stability of tamarind tartaric acid during storage and/or use. [1]However, the active substance often accumulates in the outer layers of the SC rather than penetrating deeper areas of the skin, so other vesicles such as ethosomes, transfersomes and niosomes, enhance skin penetration have emerged.[7]

Deformable vesicles made of phospholipids and ethanol are called ethosomes (ethanol content ranges from 20 to 45%) [1]. Yücel et al evaluated the effectiveness of liposomes and ethosomes encapsulating rosmarinic acid (with antiaging properties) for transdermal delivery and found that ethosomes had better skin penetration than liposome and rosmarinic acid solutions and transdermally higher throughput. This means that ethosomes can deliver RA more effectively to the skin's deeper layers.[8]

2.2. Nanoemulsions

Nanoemulsions are composed of two immiscible liquids and can be prepared as oil-in-water (O/W) and water-in-oil (W/O) emulsions.[1, 9]

Nanoemulsions could deliver both hydrophilic and hydrophobic components into the skin. Due to the small droplet size of nanoemulsions, the loading is high, so the skin penetration can be improved and the concentration of phytoc can also be increased. In terms of cosmeceutical properties, nanoemulsions outperform macroemulsions and microemulsions due to smaller nanoparticle formation of 10–200 nm so for larger surface area, higher stability and desirable aesthetic aspect.[10]

Pomegranate peel contains antioxidant polyphenols with light-protective properties, including ellagic acid (EA) and gallic acid (GA). When comparing free EAF to EAF-loaded NEs, a 2.2-fold increase in the amount of gallic acid retained in the stratum corneum was observed. Only when nanoemulsions were used to apply to the skin could GA and EA reach the viable epidermis and dermis. [9]

Ranjit K Et al. formulated a nano-emulsion-based gel loaded with ferulic acid (which significantly protects the skin from oxidative stress caused by UV rays) and optimized the formulation, which has been shown to improve drug permeability and enhance UV protection activity. This is because fa droplets encapsulated by nanoemulsions have very small nanosize (102.3±1.14 nm), resulting in a larger surface area. [4]

2.3. Lipid nanoparticles

Solid lipids were used to create the initial form of SLN. Nanostructured lipid carriers (NCLs) consist of a mixture of solid and liquid lipids. In comparison to NLCs, SLNs have a higher occlusive effect, owing to the higher degree of crystallinity of the SLNs matrix, whereas the lipid matrix of NLCs is less structured, resulting in an amorphous structure that provides stable characteristics and improves the capacity of the active components. [1]

The moisturizing capacity of SLN (serine-SLN) loaded with serine (one of the components of natural moisturizing factors) and polysaccharide-rich reed (reed) root extract (RRE) was studied. The hydrophobic character of the lipid utilised as a core material could aid the transport of hydrophilic substances like serine through the SC layer, and that is why SLN was chosen as a nano-sized carrier of serine. In vivo assessments of skin moisture content in adult female volunteers indicated that both moisturisers could enhance skin moisture content whether administered alone or in a hydrogel with two moisturisers. In addition, as compared to hydrogels without polysaccharide-rich reed root extract, the hydrogel containing 0.25 % polysaccharide-rich reed root extract resulted in a considerable improvement in skin water content. The findings suggest that both lipid-based nanocarriers and RRE can successfully transport serine into the skin, which could be a potential technique for effectively moisturising the skin.[1]

2.4. Polymeric-based nanosystems

Polymer nanoparticles, including nanocapsules and nanospheres, are composed of polymeric matrix. [1] In addition to being a coating for liposomes, chitosan is a natural polymer which may be formed into nanoparticles, as discussed above. It is because the mucoadhesive properties as well as transepidermal penetrating abilities are attained due to the availability of chitosan breaking tight junctions between the cells. Furthermore, chitosan is derived from nature, possesses excellent biodegradability and biocompatibility, degradation products are harmless to the human body, and it does not accumulate in the body. Polymeric nanoparticels are currently being employed successfully in cosmetic research and development by lowering cytotoxicity, extending, and targeting the release of bioactive compounds, such as those produced from plants. [7]

3. Marine-based cosmeceuticals

Marine bioactive active ingredients cosmeceutical formulations are the trend of cosmeceutical development. As plant-derived components have certain restrictions due to the fact that plants often grow quite gradually and their chemical nature alters seasonally.

Numerous kinds of bioactive compounds, such as collagen, carotenoid pigments, phlorotannins, polysaccharides, chitooligosaccharide (COS) derivatives, enzymes, peptides, and other natural materials, have been extracted from marine microbes for cosmeceutical applications. [11]

Sea creatures can grow swiftly and cost-effectively in a variety of environments such as macroalgae and microalgae. Besides, marine components are also created sustainably by cultivating marine

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microorganisms that can be grown in fermenters far away from the ocean, ensuring that they do not damage the marine ecosystem in comparison to plant-derived chemicals. [12]

Marine macroalgae are classed as algae and fall into four categories: phaeophyceae (brown algae), rhodophyceae (red algae), chlorophyceae (green algae) and cyanophyceae (blue-green algae). These algae extracts a wide range of bioactive substances, including vitamins, amino acids, carbohydrates, minerals, lipids, and other bioactive substances, which are then employed in a variety of cosmeceutical products. [11] In cosmeceuticals, marine algae have achieved immense popularity due to their chemical diversity and unique possibilities. Anti-blemish, skin healing, seborrhea treatment, and inflammation reduction are all possible benefits of microalgae-derived active substances. In addition, the extracts of microalgae include a wide variety of active ingredients, which assist in accelerating the healing process and maintaining skin hydration. [13]

Astaxanthin is a natural carotenoid produced by a variety of organisms and microorganisms, including microalgae, bacteria, yeasts, protists, and plants, as well as aquatic creatures like fish and crustaceans. Natural astaxanthin is mainly from Phaffia rhodozyma and Haematococcus pluvialis. The strong abilities of antioxidant and anti-aging properties of astaxanthin allow it to be widely used in cosmetics and cosmeceuticals.

It is believed that astaxanthin may be useful in the treatment of dermatitis. It is because to minimise an adverse reaction that produces dermatitis, the allergen must be removed before it penetrates the skin. Before exposure to allergens, a suitable quantity of antioxidants in the skin would oxidise and lower allergen levels. Thus, astaxanthin can be used as an antioxidant to relieve allergic dermatitis.[14]

Marta et al. investigated the prevalence of marine components in 88 sensitive skin cosmetic formulations (19 international brands), finding that 27 percent of the formulations contain marine-derived ingredients. Clinical evidence supports the use of Asparagopsis armata extracts (red macroalgae) and Ascophyllum nodosum (brown macroalgae) for sensitive skin. Hence, It is believed that marine elements used in sensitive skin cosmetics minimise skin inflammation and enhance skin barrier function.[15]

4. Marine bionanotechnology

Marine biotechnology has been a particularly promising area of study, as evidenced by the fact that some marine sources can give additional ingredients for bioactive compounds and/or nanocarrier formulations.

Marinosomes are liposomes made up of marine lipid extracts enriched in omega-3 polyunsaturated fatty acids, including docosahexaenoic acid and eicosapentaenoic acid, which are metabolised by epidermal enzymes. It can be beneficial to dry and sensitive skin and help to improve skin irritation. [16]

Gold nanoparticles have been researched as a valuable material in the cosmeceutical industry because of their excellent antifungal and antibacterial capabilities. [10]

The unique antifungal and antibacterial capabilities of gold nanoparticles make them popular among cosmeceutical manufacturers.

Numerous species of algae have been utilised in the biosynthesis of metal nanoparticles. Algae are a healthy and valuable source for the formation of metal nanoparticles due to their availability and abundance. They are capable of absorbing metals and reducing metal ions with improved energy efficiency, lesser toxicity, and environmental danger of cryogenic synthesis. Compared to other biosynthetic techniques, the time required to synthesize nanoparticles using algae is quite short. Numerous seaweeds of varying types and sizes have been employed to produce AgNPs.[17]

5. Nanocosmeceuticals toxicity

Despite the nanotechnology in cosmeceuticals has a promising outlook, the absence of long-term toxicological testing has raised worries regarding nanoparticle toxicity. Due to their small size, nanocarriers are able to penetrate through cell membranes and reach sensitive organs, where they interact with cells, proteins and DNA. According to some research, nanocarriers with particle sizes less than 10 nanometres could travel through human tissues like a gas, which can trigger chemical disruptions.

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Several studies have found indications that nanocarriers inhaled by humans are capable of traveling to the brain. When drug loading or encapsulation of nanocarriers is reduced, more surfactant is required to keep a nano formulation stable. The larger amount of surfactants may aggregate in human body, resulting in potential adverse reactions such as skin irritation, disruption of skin enzyme activity, resulting in abnormal body physiological function, and other potential unknown toxicity. The efficiency and safety of nanocarrier on impaired skin are still being studied. The therapeutic effects of nanocarriers are differentiated by the difference in skin conditions and structure for healthy and damaged skin.[4, 9] Because these products are not regulated accordingly, it is difficult to protect the rights and interests of consumers by relying only on the self-regulatory policies of the cosmeceutical industry. Consequently, it is essential to strengthen the establishment of harmonised laws and construct a standardised evaluation method for determining the efficacy and safety of cosmetic nanomaterials.

There is also raising safety concerns among European Commission (EC), the Food and Drug Administration (FDA), and a number of government agencies due to the present trend of increased demand for nanotechnology-based products. They have created guidelines to reduce the possible safety issues of nanomaterials. In fact, The EU provides the most compelling evidence for safety concerns concerning nanoparticles in cosmetics since it has the most stringent laws.[18] Furthermore, the EU has previously enacted regulations governing the use of nanomaterials in cosmetics, including mandated product safety evaluations. The FDA recently published a draught document titled Guidance for Industry: Nanomaterials in Cosmetic Products, despite the fact that there are no particular laws governing nanomaterials in the cosmetics industry. As a result of these proposed structural constraints, toxicity may be evaluated prior to the commercialisation stages of nanocosmeceutical-based formulations. [9] On this basis, the characteristics of nanomaterials also need to be considered, such as the physical morphology and surface chemical reactivity of nanomaterials, including size, shape, clearance, morphological influence, deposition site, and biological response.[18]

6. Conclusion

This paper provides an overview of potential active ingredients in botanical and marine cosmeceuticals and how they can improve formulation innovation under the action of different nano delivery systems. In response to customer demand, natural products originating from plants and marine organisms constitute a novel source of prospective cosmeceutical active ingredients for inclusion into new formulations.

It is believed that phytobioactive compounds not only have cosmetic effects, but also improve the antibacterial, antifungal, anticancer, and anti-inflammatory biological activities. Besides, studies have shown that marine composition has great potential. Sensitive skin may be more suitable for marine ingredients, as cosmeceuticals with marine active ingredients can be effective in reducing inflammation and strengthening the skin barrier. In addition, it can also be used as a component of nanocarriers. Different nanocarriers such as liposomes, nanoemulsions, and SLNs have been introduced to improve the low skin penetration and low solubility of natural cosmeceuticals.

At the same time, the permeability and toxicity of nanoparticles are still problems that cannot be ignored. As a result, there is a pressing need for scientific research and evaluation into their safety profile.

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