Transactions on Environment, Energy and Earth Sciences
ISSN: 2960-1924, eISSN: 2960-2300 | Volume 5
EMCEME 2025

Effective Application of Nanocarriers in Cosmetic Formulation Iteration and Upgrading

Ruofei Wu *

Xavier College Preparatory High School, California, United States

* Corresponding Author Email: wukgym@gmail.com

Abstract. This study aims to systematically explore the role and application value of nanocarriers in cosmetics. Through a review and analysis of common types of nanocarriers and their mechanisms of action, combined with previous experimental data, their performance advantages in the delivery of active ingredients in cosmetics were evaluated. The investigation found that organic carriers such as liposomes, solid lipid nanoparticles (SLNs), and nanoemulsions have shown significant effects in improving component stability, permeability, and controlled release; Inorganic nanoparticles such as titanium dioxide and zinc oxide can achieve efficient UV shielding in sunscreen, while gold and silver nanoparticles have both antioxidant and antibacterial effects. Application surveys have shown that nanocarriers have significant effects in sun protection, anti-aging, moisturizing, restoration, and oral care scenarios. However, research also points out challenges in terms of uncontrollable skin penetration, potential toxicity accumulation in the body, insufficient targeting, and risk of degradation by-products. Therefore, this study believes that nanocarriers have great potential in optimizing the efficacy of cosmetics, but in the future, it is necessary to strengthen safety assessment, material degradability, and precise targeting technology research and development to achieve a balance between efficacy and safety.

Keywords: Nanocarrier; cosmetics; cosmetic efficacy.

1. Introduction

The advent of nanotechnology in cosmetics has been the focus of many scholars in the last decade, because it possesses the capacity to change the way in which the manufacture and use of cosmetic products is done. Cosmetics that use nanocarriers, such as liposomes, solid lipid nanoparticles, and dendrimers, allow for superior delivery and effectiveness of the active ingredients contained in the products. These nanoparticles can help by increasing the stability, bioavailability, and absorption of ingredients through the skin with a view to target specific cells or tissues for an enhanced therapeutic result. Nevertheless, although many formulations of cosmetics now incorporate the use of nanoparticles, there is still a challenging issue of not only discovering the extent of their advantageous properties but also ensuring safety, efficacy, and regulatory concerns.

The purpose of this research study is to shed light on the role of nanocarriers in cosmetics, delving deeply into their kinds, purpose, and employment. The main research question addresses how these nanocarrier elements could be optimizing the action of cosmetics, especially when it comes to penetrating the skin and making the active ingredients more bioavailable. Besides that, the objective of the study is to observe various kinds of cosmetic carriers that can be used for different purposes such as cosmetic anti-aging treatment, moisturizing, and sun protection.

2. Commonly Used Nanocarriers in Cosmetics

2.1. Inorganic Particles

Inorganic nanoparticles (NPs) are widely used in fields such as drug therapy, cosmetics, and medicine imaging, among many others, due to their characteristic properties such as structural stability, wide possibilities for modification, optical, electric, and magnetic characteristics. The elements that are used today most frequently are metal oxides, silicon, fullerene nanoparticles, and quantum dots [1].

These possess exceptional UV-light absorption features and prevent the skin from harmful UV rays, which are primarily titanium dioxide (TiO_2) and zinc oxide (ZnO) [2].

Moreover, it is possible to use gold and silver nanoparticles as ingredients in cosmetics with their antioxidant and antibacterial properties, as well as stimulating skin aging and wound healing [3].
For drug delivery systems, the nano-size, physical stability, high drug loading capacity, and the ability to control drug release are the main advantages of inorganic particles, usually the drug delivery issues of the high stability of the drug and the drug release time is also longer.

2.2. Organic Lipids

Organic lipid carriers include liposomes, solid lipid nanoparticles (SLNs), nano lotion, etc. This is because of the disintegration of the particles (the so-called "soft" character) along with their good biocompatibility and adjustability; such carriers can be adjusted to different sizes as required to achieve the best delivery effect of drugs [2]. For preparing the nanocarriers for skin moisturizing, liposomes are one of the first samples of a method that is able to improve the transdermal absorption capability of the active ingredients and can be extended to the skincare companies such as aging and moisturizing, while the solid lipid nanoparticles are mainly concerned with the sunscreens to enhance the barrier function of skins and bioavailability of the active ingredients [3].

Nano lotion is part of another type of drug delivery system concerned with organic liposomes, which has better light transmittance and stability than oil-soluble ingredients, can formulate more appealing cosmetics with better texture, and can enhance the release of the cosmetic ingredients. Also, it is the case that its particle size is 10-200 nm, which can penetrate the skin barrier better, and especially for deep moisturizing, active ingredient dissemination, etc. [4].

3. The Role of Nanocarriers

3.1. Activity

The activity of nanocarriers mentioned here is mainly manifested in their ability to enhance the utility value of active ingredients in drugs or cosmetics, mainly by improving the stability, targeting, and bioavailability of drugs.

Researchers have determined the promoting effect of nanocarriers on the activity of nanoparticles through different methods. Foteva used anti-aging and moisturizing products as examples to illustrate that liposomes can effectively increase the skin permeability of active substances[5]. The particle size was 100nm, which was appropriate to use in transdermal therapy and measurement of particle size. It was also its strength in the water supplementation process and in wrinkle prevention. The better delivery of active ingredients into the skin layer is because of the better penetration of the liposomal skin barrier, which ends up increasing the therapeutic effect of the product.

Moreover, the effectiveness is boosted by the incorporation of gold nanoparticles and silver nanoparticles into the cosmetics formulation.

3.2. Persistent

Nanocarriers achieve their long-term effectiveness through controlled release so that the effects of active substances can be prolonged, which prevents the appearance of aged-looking skin. It could be seen as a drug or cosmetic additive with low dosing and longtime effect.

Kashapov et al designed drug-loaded solid lipid nanoparticles by utilizing an optimal high-pressure homogenization method and studying the in vitro release profiles of the prepared SLNs as part of their research work[1]. The results of the study demonstrate that SLNs have the potential of releasing usually encapsulated actives continuously, therefore solid lipid nanoparticles might be used as a base for a long-term moisturizing or UV protective product formulation.

Furthermore, the investigation report by Yadwade et al. showed that the liposomes and nanoemulsions are the best approach for the prolonged storage of cosmetic products. The continuous release testing of simulated skin models over 24 hours proved that negatively charged liposomes are capable of creating a protective layer with negatively charged surface on the skin, disrupting the effective content of products, and preventing the loss of them; This principle also increases the efficiency of cosmetics like sunscreen or anti-aging with liposomes [4]

3.3. Permeability

Permeability implies the capacity of the carriers to enter the skin or other biological barriers, providing a means for transportation of drugs or active ingredients to the site of target action. For the cosmetics and drugs to exert their effect, they need to have a certain level of permeability. And if you intend these products to influence deeper skin layers or cross the blood-brain barrier, the carrier's permeability should be improved.

In a study published by Yu et al, various examples of nanocarriers such as nanoparticles, liposomes, and dendritic polymers were found to be efficient during the penetration of the stratum corneum by hydrophilic and lipophilic ingredients[6], overcoming the skin barrier, increasing the transdermal absorption of drugs and substances, decreasing the local irritation and systemic side effects. Additionally, nanocarriers with a specific structure, such as super deformable vesicles, are more capable of penetrating and adhering to the dermis level, making it possible to deposit more active ingredients over time. Therefore, it has been argued that they have a better skincare and anti-aging effect [7].

4. Application Scenarios

The application of nanocarriers in the field of cosmetics is very extensive. For example, sunscreen and UV filter products used in daily life contain TiO_2 and ZnO nanoparticles that not only reflect and scatter UV rays but also improve the coverage efficiency of UVA and UVB due to their nanoscale properties. At the same time, they reduce the heaviness of the skin surface after use, effectively shielding harmful radiation while maintaining a refreshing skin feel [2]. Hegde et al. found that nanocarriers utilizing polyphenolic compounds can enhance UV absorption and antioxidant properties[8], thereby exhibiting better effects in resisting free radical damage and delaying photoaging. At the same time, the stability of the surface coating of TiO_2 nanoparticles in water environment directly affects their phototoxicity and environmental safety. The Al_2O3 coating layer can effectively slow down photoaging and reduce ecological risks, while the SiO_2 coating layer is more easily dissolved, leading to exposure of the active core[9].

Anti-aging products are also one of the better applications of nanocarriers. The new generation of nanostructured lipid carriers, liposomes, and fullerenes can significantly improve the solubility and transdermal absorption of active ingredients such as flavonoids, vitamins, and peptides, exhibiting stronger efficacy in antioxidant, collagen synthesis, and photoprotection [10]. Preclinical studies have shown that this type of carrier not only enhances the stability of components such as retinol and coenzyme Q10, but also achieves controlled release, reduces irritation response, and thus brings long-lasting effects in moisturizing, antioxidant, and anti-inflammatory aspects [11].

Nano lotion and SLNs are often used for deep moisturizing and repairing. They rely on small particle size and high specific surface area to achieve better penetration of skin barrier, so as to efficiently deliver hydrophilic and hydrophobic ingredients to deep skin[12]. This can not only enhance the hydration status of the skin, but also improve the repair ability of damaged areas, thus having significant advantages in moisturizing and repairing products [4,5].

In addition, nanocarriers have also shown potential in oral care. Nano hydroxyapatite, due to its high similarity with enamel structure, can fill subtle cracks and promote remineralization, thus playing a role in desensitizing and strengthening enamel products. This mechanism not only provides protective function for teeth but also repair function for teeth [3]. Many studies have shown that the ability of

nano zirconia and titanium dioxide can significantly improve the mechanical properties and antibacterial ability of denture bases. The addition of nanoparticles in root canal sealants and bone transplant materials is also promising, as they can stimulate adhesion to tooth tissue and accelerate the remineralization process [13].

5. Challenges

5.1. Uncontrollable Infiltration

The structure of the skin is relatively complex. Therefore, it is difficult for nanocarriers to penetrate the skin through exogenous reagents containing active substances [14]. Among the various characteristics of skin composition, it is mentioned that some topical drugs and cosmetics with added nanocarriers cannot specify the degree or pathway of penetration into the skin, which may depend on variables such as particle size, surface charge, and carrier form [15].

5.2. Accumulation of Nanocarriers

Nanoparticles may cause toxicity issues as their accumulation in vivo, especially during continuous use, can double their harm. A study by Sawers Arg ü elles et al mentioned that some nanoparticles, such as silver nanoparticles and gold nanoparticles[15], often stay in the skin and other tissues for a long time. This accumulation can lead to chronic skin irritation or toxicity.

5.3. Enhance Targeting Capability

In recent years of research, Servatan et al, reported that a common technique in cosmetics is to label the surface of nanocarriers with antibodies, peptides, and small molecules to enhance their targeting ability, which is crucial for identifying specific receptors in the skin[14]. Therefore, it achieves more effective delivery of components with specific functions. At the same time, precision medicine entering the skin has not been well addressed.

5.4. Degradability

Saweres Arg ü elles et al clarify that although many organic nanocarriers are biodegradable in cosmetics[15], thereby addressing the environmental burden on the skin, the products produced during the degradation process may have negative side effects on human skin. This side effect is severe skin allergy, irritation, or permeability issues, especially when the skin barrier is damaged.

6. Conclusion

Nanocarriers in cosmetics are key ingredients that enhance the efficacy of cosmetics, as they help to improve stability, bioavailability, and controlled release of active ingredients. Due to the different distribution and dissemination of therapeutic drugs, carriers provide better skin permeability through organic and inorganic nanocarriers. Their product promotion efficiency in important areas such as anti-aging, moisturizing, UV protection, and wound healing continues to improve. This can be explained when it comes to the inorganic nanoparticles used for ultraviolet protection in sunscreen, or the consistency and permeability of liposomes and solid lipid nanoparticles used for additional moisturizing or anti-aging purposes.

In most cases, the practicality of nanocarriers has been demonstrated in many cosmetics, including sunscreen, anti-aging agents, moisturizers, and oral care cosmetics. In addition, nanoparticles enable sustained release and targeted delivery of nanocarriers, expanding their applications in skin hydration, collagen synthesis, and prevention of photoaging. However, their safety issues, such as skin contact control, nanoparticle accumulation, and toxicity, are tasks that require improved solutions. The future task should focus on selecting the best ingredients and studying the safety of nanocarriers in cosmetics.

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