The role of nanoparticles in cosmetics and the potential harms of enhanced absorption: a review

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Abstract. As an emerging technology, Nanotechnology has already been used in many fields of technology and science, e.g., medicine, electronics, and materials science. In cosmetics too, nanotechnology can play a significant role. Even though the method of producing nanoparticles is not yet very mature, they pose significant potential in additives to cosmetics. Moreover, because of their unique properties, they can largely enhance the performance of cosmetics and cosmeceuticals. Herein, the properties and mechanisms of some typical nanoparticles for cosmetics were explained. Furthermore, some potential harms of nanoparticles in cosmetics, for example, damages resulting from the chemicals carried by liposomes, were discussed. This review intends to deepen the understanding of nanoparticle applications that can improve cosmetics quality.

Keywords: Nanoparticles, Cosmetics, Liposomes, Skin Absorption.

1. Introduction

A nanoparticle is a particle with a diameter of less than 100nm. Nanoparticles are present in many areas. For example, they can enable creative therapies to be performed in medicine. Cosmetics are used daily to protect consumers' skin, enhance their appearance, or deal with dermal problems like acne, scurf, sunburn, etc. Recently, the combination of nanoparticles and cosmetics has enhanced their performance in various aspects, e.g., improved antibacterial functions. Besides, recent years have seen an increased number of discussions on the use of nanoparticles in the cosmetics industry and their advantages and disadvantages. Therefore, it is meaningful to dive deeper into the relationships between the use of nanoparticles and quality improvements in cosmetics.

Cosmetics have a long history. In ancient times, cosmetics were used only by the upper class as a symbol of wealth and status. In the 20th century, accelerating technology enabled better and safer cosmetics to be produced and utilized. It is common for ordinary people to use cosmetics, and there is an increasing demand for high-quality cosmetics. Several attempts have been made to enhance the performance of cosmetics, including the addition of nanoparticles like titanium dioxide (TiO_2) to meet this demand.

Titanium dioxide is a nanoparticle used in sunscreens. In the past, ancient civilizations used rice or oil to protect themselves from sunshine, which was not ideal. Nowadays, with the help of titanium dioxide, sunscreens can effectively safeguard our skin from sunburn.

This review discussed multiple nanoparticles, including titanium dioxide that are applicated in cosmetics. These include gold nanoparticles (AuNPs), silver nanoparticles (AgNPs), liposomes, carbon black, and dendrimers: a polymer. This review will not only provide insight into the properties of the nanoparticles but also discuss their benefits and potential harms.

2. Titanium oxide

Titanium oxide is widely used in cosmetics, especially sunscreens, because of its white color and its anti-ultraviolet properties. Yang et al. (2003) [1] stated that regardless of the particle sizes, TiO_2 effectively absorbs UV radiation, which can be explained by the solid band theory, and nanoscale TiO_2 is better at absorbing UV light. When a TiO_2 molecule is irradiated with UV light with a wavelength less than 400nm, which is its approximated absorption edge, the electrons in the valence shell will be excited to a higher energy level, producing pairs of electrons and holes. Because of

increased surface area, the nanoscale TiO_2 absorbs much more UV light than the one used for pigments. A main advantage of TiO_2 is that it is stable and cannot react with other chemicals easily [2]. Also, TiO_2 has no effects like penetration or toxicity on healthy skin, so it is used in large amounts in cosmetics [3]. However, inhaling ultrafine particles, including nanoscale TiO_2, cause lung inflammation [4]. This seldom causes negative effects in cosmetics because TiO_2 particles are held in liquid or emulsion and are not volatile.

3. Gold & silver nanoparticles (AuNPs & AgNPs)

AuNPs and AgNPs are studied and used in cosmetics and cosmeceuticals because they kill bacteria and fungus. Some examples of products that are used are face packs and deodorant [5]. The mechanism of the antibacterial functions of the AgNPs is explained briefly below.

The Ag^+ ions released from the AgNPs penetrate through the bacteria's cell wall and membrane before denaturing the ribosomes and interrupting protein synthesis. Then, the silver ions neutralize the respiratory enzyme on the cytoplasmic membrane and interrupt ATP production. After that, reactive oxygen species cause membrane disruption and prevent DNA replication with silver ions. Finally, the silver nanoparticles denature the membrane to make holes, so the organelles can be released [6].

Cui et al. (2012) [7] pointed out that AuNPs can perform antibacterial actions in two ways. One is to adhere to the membrane from the inside to decrease the amount of ATP produced and interrupt metabolism, and another is to attack the ribosomes. Here, it can be seen that these mechanisms are like that of AgNPs.

4. Carbon Black

Carbon black is produced from the incomplete combustion of fuels like coal, petroleum, and coal tar. Also, it can be formed by cracking ethylene. It is a form of carbon with a high surface area [8]. It is compatible with almost all common solvents and substances and Insoluble in water and other solvents, allowing it to be widely applied in cosmetics. The SCCS has stated in a report [9] that carbon black with particle size larger than 20nm or at a concentration not exceeding 10% can be safely applied on healthy skin. However, research [10] has also shown that carbon black can be carcinogenic if overused.

5. Dendrimers

As their name suggests, dendritic polymers comprise a spherical structure consisting of a core from which symmetrical units are formed, which is why dendritic polymers are multifunctional. When functioning on the skin, the movement is highly dependent on the size and surface charge of the polymer. It is possible to alter their structure and properties to obtain the desired characteristics. Likewise, through various synthesis methods, the functional groups on the structure can be changed to modify the properties of the polymer [14]. Its properties of monodispersity, polyvalence, and stability have allowed it to be used as an ideal drug-carrying agent. Thanks to its unique structure, the drug can be attached to and released from both the inner side and the surface [12].

6. Nanoparticles for enhanced absorption

It is usually liposomes that are used in cosmetics to enhance the absorption effect. Liposomes have many variants, including transferosomes, niosomes, marinosomes, etc. Liposomes are small vesicles built up artificially with cholesterol and natural non-toxic phospholipids. Because of their nanoscale size and hydrophobic and hydrophilic character, they are commonly used in chemical-delivery cosmeceuticals [16].

Liposomes are spherical. Their aqueous solution core is surrounded by one or more hydrophobic lipid bilayers so that the hydrophilic solutes in the core cannot pass through the bilayers. Because hydrophobic chemicals can also be attached to the bilayers, liposomes can carry both hydrophilic and hydrophobic substances at the same time. During the drug delivery process, a liposome associates with other bilayers like the cell membrane and sends its contents into the cell [11]. Liposomes are highly multifunctional in cosmetics. When liposomes are empty, they can help repair dry or eczema-affected skin by interacting with the lipids, proteins, etc., to make the skin cells return to a healthy state. A good example of a chemical that can be delivered through liposomes is vitamin K1. Its molecules are very lipophilic, enhancing its ability to be absorbed by the skin when carried by liposomes. This vitamin has many crucial effects like antioxidation, suppressing skin pigmentation, and resolution of bruising like mitigating the symptoms caused by irradiation of laser beams [15]. Liposomes can also increase the stability of chemicals used in cosmetics by encapsulating them in the lipid bilayers, hence increasing the product's shelf life. Vitamin C, an antioxidant that protects the skin from free radical attacks and prevents skin inflammation, is unstable under UV radiation or harsh environments. Therefore, liposomes are utilized to enhance the stability of vitamin C [13]. Liposomes can select the target cells as well. This can be achieved by altering the charge on the membrane, or adding specific antibodies, proteins, etc., to the liposomes. Also, liposomes can be designed to react differently to designated pH values and temperatures [17].

Liposome has many advantages. Firstly, it can avoid the side effects that may happen when absorbed by the skin. Secondly, it is non-toxic and biodegradable. Also, it can increase drug accumulation in the skin, which grants itself substantivity with biological membranes. As mentioned before, it can carry hydrophobic and hydrophilic chemicals simultaneously and moisturize and repair dry skin. However, although liposomes can protect the chemicals carried from being oxidized, they are themselves vulnerable to degradation through hydrolysis or oxidation, causing negative effects on the cosmetic's quality. Some variants of the liposome also show low encapsulation efficiency [18]. One way to solve these problems is to design and utilize liposomes with a more reliable structure.

7. Further discussion on whether enhanced absorption is necessarily good or not

Enhanced absorption of cosmetics can largely improve the consumers' skin quality. However, the absorption of cosmetics can also potentially cause harm. This is caused by the chemicals in them. Alpha hydroxy acids, for example, glycolic acid, may cause skin irritation. The United States Food and Drug Administration has warned consumers that the acids can increase photosensitivity to the sun. Benzoyl peroxide, used to kill bacteria and treat acne, can cause dry/peeling skin and redness. Propanediol helps the formulation of the product to penetrate the skin better, but it can potentially cause skin sensitivity if a large amount is used. PEG-100 Stearate, an emulsifier, is a highly comedogenic ingredient that tends to cause blackheads by blocking the skin's pores. If the letters PEG are spotted on a cosmetics product, it probably means that the ingredient is comedogenic. Many other chemicals in cosmetics may cause harm to the skin if absorbed too much, but they are outside the scope of this review.

8. Conclusions

In summary, providing their unique properties, nanoparticles are already playing an important role in daily necessities like cosmetics. Despite the significant enhancement they can bring to beauty products, their shortcomings are significant, e.g., they lack uniform regulations, which means companies sometimes may not know to what extent they should use the nanoparticles. What's more, their forementioned potential harms cannot be ignored. There are still many issues caused by nanotechnology waiting for researchers to dive deeper into and find solutions to, because only by

doing these can nanotechnology be made better use of not only in cosmetics or cosmeceuticals but also in many other fields of pure and applied science.

References

[1] Yang, H., Zhu, S. and Pan, N., Studying the mechanisms of titanium dioxide as ultraviolet-blocking additive for films and fabrics by an improved scheme [J]. Journal of Applied Polymer Science, 2004, 92 (5): 3201 - 3210.

[2] Skocaj M, Filipic M, Petkovic J, et al. Titanium dioxide in our everyday life; is it safe? [J]. Radiology and Oncology, 2011, 45 (4): 227 - 247.

[3] Titanium Dioxide. [EB/OL]. https://www.safecosmetics.org/chemicals/titanium-dioxide/#ref22.

[4] Oberdörster, G. Pulmonary effects of inhaled ultrafine particles [J]. International Archives of Occupational and Environmental Health, 2000, 74 (1): 1 - 8.

[5] Lohani, A., Verma, A., Joshi, H., et al. Nanotechnology-Based Cosmeceuticals [J]. ISRN Dermatology, 2014, 843687.

[6] Yin, I. X., Zhang, J., Zhao, et al. The Antibacterial Mechanism of Silver Nanoparticles and Its Application in Dentistry [J]. International Journal of Nanomedicine, 2020, 15:2555 - 2562.

[7] Cui, Y., Zhao, Y., Tian, Y., et al. The molecular mechanism of action of bactericidal gold nanoparticles on Escherichia coli [J]. Biomaterials, 2012, 33 (7): 2327 - 2333.

[8] Fytianos, G., Rahdar, A., & Kyzas, G. Z. Nanomaterials in Cosmetics: Recent Updates [J]. Nanomaterials (Basel), 2020, 10 (5): 979.

[9] Carbon black. [EB/OL]. https://en.wikipedia.org/wiki/Carbon_black.

[10] Scientific Committee on Consumer Safety (SCCS), et al. Opinion of the Scientific Committee on Consumer safety (SCCS) – Second revision of the opinion on carbon black, nano-form, in cosmetic products [J]. Regulatory Toxicology and Pharmacology, 2016, 79: 103 - 104.

[11] Baan, R., Straif, K., Grosse, et al. Carcinogenicity of carbon black, titanium dioxide, and talc [J]. The Lancet Oncology, 2006, 7(4): 295 - 296.

[12] Kaul, S., Gulati, N., Verma, D., et al. Role of Nanotechnology in Cosmeceuticals: A Review of Recent Advances [J]. Journal of Pharmaceutics, 2018: 3420204.

[13] Akbarzadeh, A., Rezaei-Sadabady, R., Davaran, S., et al. Liposome: classification, preparation, and applications [J]. Nanoscale Research Letters, 2013, 8 (1): 102.

[14] Liposome. [EB/OL]. https://en.wikipedia.org/wiki/Liposome.

[15] CampaniV, Marchese D, Pitaro MT, et al. Developmentof a liposome-based formulation for vitamin K1 nebulization on the skin [J]. International Journal of Nanomedicine, 2014, 9: 1823 - 1832.

[16] Vinardell, M. P., & Mitjans, M. Nanocarriers for Delivery of Antioxidants on the Skin [J]. Cosmetics, 2014, 2 (4): 342 - 354.

[17] Ahmadi Ashtiani, H. R., Bishe, P., et al. Liposomes in Cosmetics [J]. Journal of Skin and Stem Cell, 2016, 3 (3): e65815.

[18] Rahimpour, Y., & Hamishehkar, H. Liposomes in cosmeceutics [J]. Expert Opinion on Drug Delivery, 2012, 9 (4): 443 – 455.