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REVIEW ARTICLE

Nanotechnology in cosmetics: Opportunities and challenges

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HIGHLIGHTS

> The use of nanotechnological applications in the cosmetic industry was examined.

> The use of different nano-sized materials in cosmetics was examined.

> The safety requirements of cosmetic products were determined.

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ABSTRACT

The word "nano" is derived from the Greek word "nanos" meaning "dwarf" and corresponds to a size of 1 x 10^{-9} meters. The technology dealing with these tiny substances is also called "nanotechnology". The famous American physicist Richard Feynman (1918–1988) proposed for the first time that there is a nano-sized world. Feynman addressed the mystery of nanoscales for the first time in his speech titled “There is more room below” at a conference in 1959. The scientist reported that many new discoveries would emerge if he could work in the atomic and molecular dimensions he imagined. In this speech, which is accepted as the beginning of nanotechnology, it was emphasized that nanoscale measurement and production methods should be developed first in order to be engaged in nano-scale studies. Nanotechnology is the creation of functional structures at nanometer scales by combining atoms and molecules. Nano is a scale, nanotechnology means technologies developed at that scale. Therefore, dealing with nanoscience and nanotechnology requires a multidisciplinary field. Its target is not a specific subject; it creates a wide coverage area that requires collaboration and includes many researches. With atoms and their arrangement; it means making innovations in materials, production techniques and developing new products with superior features suitable for needs. Nanotechnology is widely used in cosmetics, especially in moisturizers, sunscreen and anti-aging products: Apart from these, there are different uses such as make-up products, perfumery, oral and hair care products. The number of products containing nanoparticles is increasing day by day in the cosmetics industry.

1. Introduction

Nanotechnology can be explained as a field in which popular and widely used raw materials, devices and systems with a size range of 1-100 nm are designed, structurally examined and their applications are investigated. Nanotechnology is known as the technology of the future and it was around the same time that the cosmetic industry met it. It has been seen that it is used in the sector, especially in areas such as protection against harmful sun rays, long-lasting cosmetic products, pigment production and skin penetration Therefore, sectoral development in which nanotechnology is used in cosmetics is gaining more and more importance day by day [1]. The reason why nano-sized products are preferred in cosmetics is the color they gain with their size, durability, transparency and antimicrobial properties [2]. With these attractive properties, nanomaterials are becoming preferred for the cosmetic industry.

2. Nano Diversity in Cosmetics

2.1. Mineral-Based Cosmetic Ingredients with Nano Dimensions

Cosmetics containing sunscreen are mineral content. Its effectiveness varies depending on the size of the nanoparticles in the product used. Titanium and zinc

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containing nanoparticles can be added to sunscreens with sizes around 20 nm. It is known that these products provide different advantages, one of these advantages is to obtain sufficient UV protection effect in less use [3,4].

2.2. Other Nano-Sized Materials Used in Cosmetics

Many well-known cosmetic companies claim that their products contain different nano-sized materials such as nanoparticles, liposomes, fullerenes, nanotubes and quantum dots [3,4].

Types of Nanomaterials Used in Cosmetics Are:

2.2.1. Liposomes

Structurally, liposomes are natural or synthetic phospholipids that are purely GRAS (generally considered safe) products of the aqueous volume. These phospholipids form bilayer vesicles with a lipid bilayer. By their arrangement, the lipid bilayer of liposomes is similar to the cell membrane, which supports the release of its contents. For this reason, they can easily pass through the cell membrane [5,6]. Thus, they are preferred in formulations in the field of cosmetics due to their rapid absorption. Of the liposomes, transferosomes, niosomes, and etosomes are examples of the most rapidly absorbed [6–9].

2.2.2. Nanoemulsions

It is obtained by dispersing a liquid in another liquid as nanoscale droplets [10]. Stability may vary according to synthesis methods. In addition, GRAS products are used in its synthesis. Depending on the size of the obtained nanoemulsion, its properties such as stability, content carrying capacity, absorption and shelf life may change [9,11].

2.2.3. Nanocapsules

On the other hand, nanocapsules are nano-sized structures consisting of a polymeric capsule surrounding an aqueous or oil-based core. Experiments on pigskin have shown that the use of nanocapsules reduces UV filtered octyl methoxycinnamate penetration compared to non-nanosized ones [12].

2.2.4. Solid Lipid Nanoparticles (SLN)

They are nanocomponents that are solid at body temperature, containing stabilizing agents and lipid droplets in their structure. They are known to be used to protect encapsulated structures. In addition, it has been understood that the active ingredients in formulations prepared using SLN can more easily pass into the stratum corneum [13]. Studies with SLM have shown that it increases hydration on the skin compared to placebo [1].

In another study, it was found that when used with sunscreens, they increase the UV filtration properties. In a study conducted using this method, it was observed that the UV filtration property of 3,4,5-trimethoxybenzoylkit increased when included in SLNs [14].

2.2.5. Nanocrystals

Their structures are clustered formations of between 100-10,000 atoms. The sizes of these clusters usually have a scale of 10-400 nm. Due to their size, their chemical and physical properties may differ. When used, they cause controlled, safe and effective absorption through the skin [15].

2.2.6. Nanosilver and Nanogold

One of the structures commonly used in the cosmetics industry is nanosilver. Cosmetic manufacturers widely benefit from the antimicrobial property of this structure. Examples of personal care and cosmetics produced for this purpose are products such as antimicrobial armpit dedorants with 24-hour effect. It is understood that it can be used in the development of mouthwash and oral care products as a different application area. Another structure, nanogold, is seen to be used in cosmetic products such as hair dyes and masks. It is also known to be added to mouthwashes and toothpastes as a personal care product [16].

2.2.7. Dendrimers

Dendrimers are about 20 nm in size, branched structures with a symmetrical backbone and contain functional groups at their ends. The usage areas vary according to these functional groups. The structures of dedrimers can be monomolecular, monodisperse and micellar. They gain functionality according to the structure of their functional groups [17,18].

2.2.8. Cubosomes

Cubosomes are cubic-shaped structures with a biphasic structure. They usually contain sulfates and phospholipids and crystal structures in their structures. When evaluated in terms of size, they are classified as nano or submicron [19]. Cubosomes are formed as a result of the reaction of the material selected as a sulfactant and the crystal structure in the presence of microstructures in the aqueous medium. Their surface areas are quite large due to their geometry. They have a low density and also very dilute solutions can be prepared easily. Both polar and non-polar groups on them provide advantages and they also have high heat stability [1,12,20]. They are widely preferred in the commercialization of cosmetic products due to the stated reasons and also due to the low cost.

2.2.9. Hydrogels

Structurally, they are three-dimensional polymers that swell in water or biological fluids linked by chemical or physical cross-links. They are widely used in rejuvenating care products due to their net-like systems and hydrophilic nature [20].

2.2.10. Bucky Balls

Fullerelen (C60) is the most remarkable and widely used nanomaterial. Structurally, its diameter is around 1 nm. It is used in expensive anti-aging creams due to its strong radical scavenging effect [1].

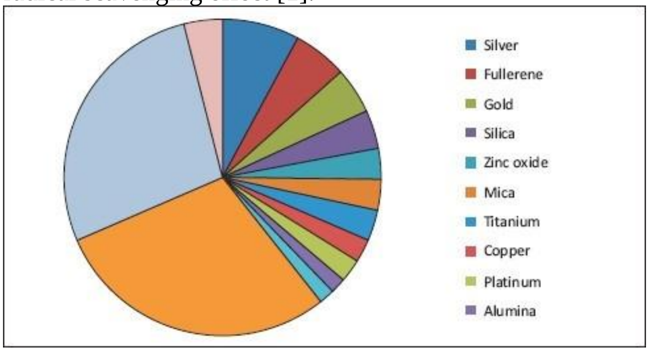

Figure 1. Basic nanomaterials used in cosmetics

3. Characterization Methods for the Safety Assessment of Nanoparticles in Cosmetics

The views of the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) relate to risk analyses (25) to assess potential adverse health and environmental impacts of nanotechnology products, as well as research into nanomaterials [21]. The particular properties of nanomaterials will require new testing methodologies to identify potential injury treatments they may cause.

The following parameters can be listed in the safety evaluation of nanomaterials:

3.1. Physical and Chemical Properties of Nanomaterials

Physical properties of nanomaterials such as shape, size, agglomeration status, surface area, size, morphology should be determined [22].

3.2. Mathematical Modeling

These predictive models range from simple, experimental algorithms to complex mathematical equations that sometimes require knowledge and estimation of parameters that are not available experimentally. However, since none of these models include data compounds, they can't be applied with confidence as they cannot predict what might happen when such substances come into contact with the skin [23].

3.3. Microscopic Techniques

More useful information can be obtained from *in vitro* studies by microscopic examination of the skin after treatment. Although absolute quantification is not possible, visualization of the tissue to which an active has been applied can provide valuable information [23,24]. The analysis methods for evaluation of samples are given in Table 1 below.

Table 1. Methods used for imaging techniques [23].

Techniques used	Advantages
Laser scanning confocal microscopy (LSCM)	• 3D views of the skin samples obtain with high resolution electron microscopy images. • Demonstration of efficacy in formulation containing nanomaterial in cosmetic product. • Visualize the affinity of particulate vectors for follicular opening
High-resolution transmission electron microscopy	• Visualize individual particles in ultra-thin sections of tissue • Can use X-ray analysis to identify the chemical composition of the visualized vector
Particle induced X-ray emission (PIXE)	• Large fields of view • Ease sample preparation • Facile elimination of artefacts
Radio labeling with the positron emitter ^{48}V	• Ultra-sensitive • Easy to use • Provides different fields of view • Shows individual positron tracks • Useful for localizing particles to specific structures in/on the skin

3.4. In Vitro Methods

Although there are various methods and technologies for studying the molecular mechanisms involved in the biological activity of compounds, only approved methods are allowed for cosmetic products. These approved methods should be used for testing the safety assessment of cosmetic ingredients [23,24]. The proven *in vitro* tests used in the field are given in the Figure 2 [23].

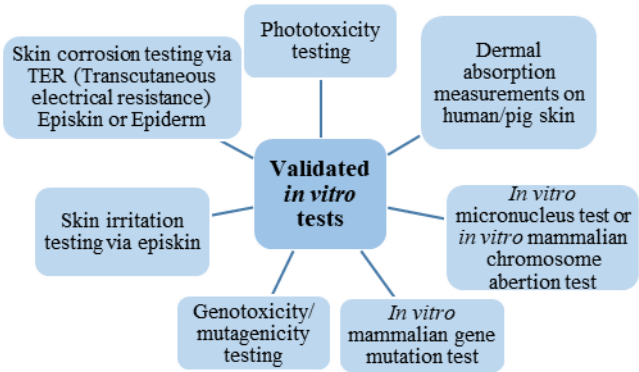

Figure 2. Some *in vitro* methods used [23]

Relevant toxicological endpoints considered important for nanomaterials are given in Figure 3 below [24].

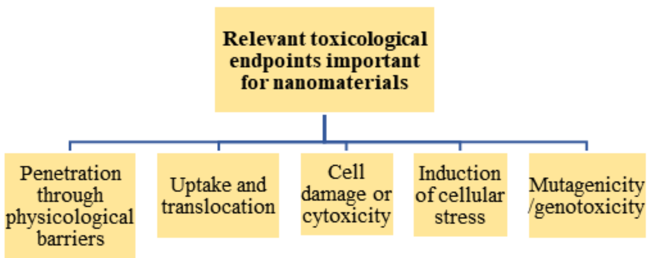

Figure 3. Relevant toxicological endpoints important for nanomaterials

4. Safety Requirements for Cosmetic Products

Cosmetic manufacturers should not lose sight of the fact that there may be some uncertainty using nanotechnology, both from a consumer response and a regulatory perspective. Leading scientific organizations such as the UK's most prestigious scientific institution, the Royal Society, and the US Food and Drug Administration, agree that nanocosmetics can have health risks and therefore require extensive research before product commercialization [25].

Although the use of nanomaterials in cosmetic products has increased day by day, no different regulation has been made regarding the safety assessment. It is involved in regulating the safety of ingredients in products in the cosmetic industry within the framework of the National Industrial Chemicals Notification and Evaluation Plan (NICNAS) in Australia. However, there is no distinction between nano or bulk sizes. The EU's Scientific Committee included animal experiments in its safety assessment of nanomaterials in cosmetic products for Consumer Products (SCCP) and evaluated whether previous findings should be corrected [26].

The European Parliament approved the re-amendment of the EU Cosmetics Directive in EU legislation. Within the framework of the new regulation requested by the European Parliament, a safety assessment procedure was required for all products containing nanomaterials. In addition, it was ruled that cosmetic products containing nanomaterials should be banned if there was a risk to human health (31). Some parts of the law are listed below:

Some *following terms:*

• Decision defines a nano-material as “an insoluble or biologically persistent and intentionally produced material with one or more external dimensions or an internal structure on the scale of 1 to 100 nm”.

• Responsible person, restrictions listed in Annexes, animal testing, safety, product information dossier, notification, safety assessment, sampling and analysis, GMP, CMR, traces of nanomaterials, and labelling, public information, claims, SUE on substances.

Before the cosmetic material is presented to the customer, it is required to submit the following information to the Commission:

• Presence of nanomaterials

• Chemical name of materials (IUPAC) and ingredients

• Projected exposure conditions

• If the Commission has negative opinions about the safety of nanomaterials, it asks them to submit an perspective on the safety of them and the exposures for the relevant cosmetic products.

• The form of the nanomaterial will be clearly stated in the ingredient substance of product. The names of these components will be written as the "nano" word.

• Special attention will be paid to its toxicological effects.

• Dimensions of particles including nanomaterials

• Impurities of the ingredients;

• Interaction of materials [27,28]

5. Conclusion

The use of nano-sized materials in the cosmetic industry is increasing day by day. Due to the superior properties of nanomaterials, it has become the focus of attention of the cosmetics industry and has taken its place in the production of cosmetics. In addition, the introduction of nanomaterials into cosmetics has caused great concerns in terms of reliability. For the purpose of ensuring the safety and effectiveness of all products, the European Union has made serious changes to the Cosmetics Directive since 2012. With this regulation, only Nanocosmetic products whose safety has been demonstrated were allowed to enter the market, and inaction was ensured for suspicious ones.

Compliance with Ethical Standards

There is no conflict of interest to disclose.

Conflict of Interest

The author(s) declares no known competing financial interests or personal relationships.

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