



Nano-Based Technology on Hair Care Cosmetics: Its Delivery, Benefits and Risk

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ABSTRACT

Hair quality is viewed as an important factor of health. It is a fundamental structure made up of simple uncomplicated filaments that provides protection from heat from either direct sunlight or any processes involved in hair care treatments. Moreover, it mirrors a person's social status and relationships, including features like youthful appearance, age, and lifestyle trends. Cosmetic products intended for hair care are used for several purposes to enhance overall hair, shaft, and scalp health. This is where nanotechnology-based delivery for hair care enters. The advancement of research and development demonstrated by nanotechnology boosts hair care product efficacy by delivering creative solutions. This review paper aims to discuss and provide an overview regarding nanotechnology and its incorporation into hair care cosmetics in order to enhance quality as well as hair care delivery. Specifically it presents a summary of all the gathered publications with relevance to nanotechnology and its application to hair care products in terms of delivery, benefits, and the risks involved with its inclusion. With this, the major findings of several studies presented that nanoparticles can increase the advantages of active substances when incorporated into hair care products and that the improved understanding regarding pathways of the hair care delivery has helped in the personalization of products which in turn improves hair cosmesis.

Keywords. Hair Care; Nanotechnology; Delivery; Benefits; Risk; Shampoo; Hair; Hair Cosmetics; Hair Dye; Hair Structure; Hair Gels

Introduction

Hair really does have a simple structure but yet actually serves essential roles in human contact. It is structurally supported by Keratin which is a naturally-occurring fibrous structural protein that is also found in the skin, and nails. Hair begins growing at the base of a hair follicle and is rooted into this tunnel-shaped structure with the bulb of the hair being the hair shaft's foundation. Cells that are alive, through division as well as proliferation develop the hair roots within that hair bulb. [1]. Hair has several other purposes towards people, this includes the defense against any and all forces, the sebaceous production, apocrine sweat generation, pheromone synthesis, and body temperature. This is also true for other purposes such as personal, social, and sexual engagement. [2,3]. As a result, hair condition is regarded as a key indicator of health [4]. With this, hair care and treatment have advanced greatly over time as novel formulations are constantly being researched in a way to satisfy needs in the cosmetic and medicinal industries. [7]. Therefore, the transition of products from the traditional system to improved formulations has been a key component of cosmetic studies. Because of peoples' heightened understanding of personal appearance, beauty, hygiene, and care, consumers have increased their utilization of hair products.

Nanotechnology is a novel field of study that is included in a branch of science that encompasses the development, description, manufacturing, use of resources, electronics, as well as nanoscale systems. The presence and advancements of nanotechnology is widely regarded as one of the most recent and important technologies in cosmetic formulation. Materials can be made sturdier, lightweight, more robust, reactive, sieve-like, or enhanced functional conductors using nanotechnology, among several other properties. What's more, cosmetic manufacturers use nanotechnology chemicals to supply enhanced UV protection, better and efficient skin penetration, greater colour, complete quality, effects that could last you longer than

the usual and a variety of other benefits. [5,6]. As a likely result of their distinctive and underlying qualities, nanoparticles are progressively being used to develop and create fresh, cutting-edge skin care products that target the hair shaft and follicle in particular.

Nanotechnology-based inventions strive to strengthen cosmetic stuff stability components, enhance not only visual quality of goods, but also direct active compounds to focused structures for controlled release and long-term effects. Tremendous study has been conducted on the use of nanotechnology to preserve the gloss, silkiness, and health of hair [32]. As a result of the constant research into new formulations to try to meet demand in the beauty and pharmaceutical industries, hair care and treatment have changed considerably throughout time. While basic hair care procedures such as washing, coloring, and bleaching are aimed at cleaning, sustaining, and complementing hair, New hair treatments are readily available as well as mostly devoted on minimizing loss of hair, expanding follicle of hair qualities, and lastly, hair infestation treatment.

Methodology

This article review focuses on the nano-based technology on hair care cosmetics. The information gathered for this review used synthesis-based review in which different studies from various databases were utilized. To elaborate, the proponents will combine a number of different pieces into a whole. Basically, synthesizing and relating information from many sources in order to examine the literature on the subject of nanotechnology and its use in hair care as well as offer suggestions in light of the review's findings. The collection of data for this review began on June 21, 2022. Specifically, this review will focus on hair, the delivery of nanotechnology in hair care products, nanotechnology in cosmetics, benefits of the application of nanotechnology in hair care, and risks associated with nanotechnology.

Characteristics and Structure of Hair

In today's society, hair has become a vital tool of self-identification and self-expression. As a result, cosmetics for adorning or changing the look of scalp hair are widely utilized. Successful cosmetic hair modification requires that constituents affect some part of the hair's normal exterior and interior structure [8].

Hair characteristics

Hair is a complex structure of unique chemical and physical properties consisting of multiple morphological components that work together as a unit [9]. A healthy hair is pigmented, silky, and shiny, as well as flexible and strong enough to endure shearing pressures. The smooth layering of the cuticle determines hair gloss, whereas the quality of the cortex which is composed of 15% keratin determines hair strength [10]. Moreover, this protein present in the hair contains a high concentration of cysteine (a sulfurated amino acid), which creates disulfide connections between molecules, giving firmness and strength to the overall structure [11]. The unprocessed hair has a well-protected structure. Its outermost layer is designed to keep the hair smooth and resistant to diffusion into the cortex when wet [12]. This characteristic of hair helps keep the integrity of its structure.

Hair structure

One of the major components of the hair's structure is the hair follicle. It is a tunnel-shaped form arranged in a stocking manner which attaches the hair into the surface of the skin. Infundibulum is one of the portions of the hair follicle that spans from the sebaceous gland to the follicular orifice. It is the main point of interaction between the environment and epithelium. Infundibulum houses microorganisms with their own immune defenses [13]. Most of the topical formulations (i.nanoparticles) accumulate in this region, between the infundibular walls and hair shaft. A vital factor for hair growth and development as well as melanogenesis is the hair bulge. This area is also part of the hair shaft which is located behind the sebaceous gland. As for the pigmentation of hairs, it is indicated by melanocytes. It also preserves hair follicle colors in succeeding hair cycles [14].

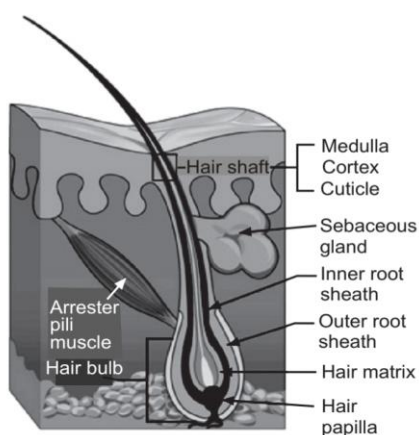


Image source: <https://solutionpharmacy.in/hair-structure>

Figure 1. Hair structure.

The second major part of hair structure is the hair shaft. It is made from keratinized dead cells which have three distinct layers. The outermost layer is called cuticle. This layer serves as a hair protection due to its scale-like structure formed by overlapping cells. Combing hair too much, exposing the hair to high heat and using chemicals like hair dyes can damage the cuticle which can consequently lose the natural shine of the hair [15]. Another component of the hair shaft is the cortex. Cortex forms a tough bundle made up of coiled fibrous cells. It contains melanin which is responsible for pigmentation of the hair. When the outermost layer of hair shaft is damaged, it exposes the cortex which will cause water loss and allow foreign material entry [16]. Finally, medulla is the deepest layer of the hair follicle which serves as a support to the hair structure. Apparently, the absence or damage of medulla does not affect the strength of the hair [17].

Nanotechnology in Cosmetics

Nanotechnology is defined as the science of atomic and molecular manipulation at a nanoscale [18]. In recent years, nanotechnology has gained tremendous development, public opinion has been influenced by the marketing of nanotechnology garnering different views both from positives and negatives [19]. The development of nanotechnology has been evident in various stems of science including medicine, electronics, and even cosmetics [18].

Nanotechnology that is employed in cosmetics has shown that properties from the use of nanoparticles in cosmetics yield better or enhanced results compared to large-scale particles, altered properties of nanoparticles from larger particles include: nanomaterials are appealing to the cosmetic industries due to their color, transparency, solubility, and chemical reactivity. [20]. Following the interest in nanotechnology in the field of cosmetics, it has been observed from surveys that major cosmetic manufacturers are employing nanotechnology in their products, some top companies that employ nanotechnology are the following: L'Oreal, Procter & Gamble, Henkel, Unilever, etc [21].

Nanomaterials

Nanomaterials, as used in nanotechnology, have different physical and chemical properties that may enhance effects or toxicity of a substance [19]. The cosmetic business uses nanoparticles in an effort to achieve more stability and long-lasting results. Nanomaterials' large surface areas make it possible for the substances to be transported through the skin more effectively. The effective penetration of nanomaterials into the skin for increased ingredient delivery, new color components, transparency, and long-lasting effects may be some of the key goals of their use in cosmetics. [36]

Table 1. Nanomaterials employed in cosmetics manufacturing.

NANOMATERIALS	DESCRIPTION
Liposomes	enhance the penetration of substances and absorption to the skin, with provision of continuous supply of active ingredients into the cells, as well as ease of preparation make them suitable for use in cosmetics as a nanomaterial [22].
Nanoemulsions	are metastable systems which are a dispersion of nanoscale droplets; nanoemulsions increase shelf-life, stability, and suitability of a product to carry active ingredients [23].
Nanocapsules	are made of polymeric capsules that surround an oily or aqueous core. In a study by Hwang & Kim, 2008, showed that nanocapsules decrease the penetration of octyl methoxycinnamate, a UV filter, in pig skin [24].
Solid Lipid Nanoparticles	are oily, lipid-based droplets that are stabilized by surfactants. They serve to prevent the degradation of encapsulated items, enhance the entry of substances into the stratum corneum, and have also been proven to possess UV-resistant qualities. [25],[26].
Nanocrystals	are aggregates that allow effective and safe entry through the skin [27].
Nanosilver and Nanogold	both are used as antibacterial agents in cosmetic preparations [18].
Dendrimers	are nanomaterials suitable for multi functionalization [18].
Cubosomes	cubosomes may contain both hydrophilic and hydrophobic molecules and have heat stability. They are created when surfactants and water are combined at the microstructure level in a specific ratio.[28].
Hydrogels	are cross-linked networks of macromolecular compounds, these cross-links have high water absorption capacity [29].
Buckyballs	are known to have properties that can scavenge free radicals [30].

Delivery of Nanotechnology in Hair Care Products

Shampoo

Shampoo compositions today go beyond the level of simple hair cleansing. Additional benefits include conditioning, lather creaminess, compatibility enhancement, and smoothing the hair surface [42]. Nanoparticles have been utilized in scalp and hair shampoos to improve resident contact time, allowing active ingredients to establish a protective barrier and trap moisture within the cuticles. The hydro-lipid emulsion layer is visible when the cuticle layer is opened by hot water, allowing for external water absorption while preventing internal water loss. Silicone, because of its hydrophobic properties, will build up on the scalp rather than permeate the hair in regular washes [43]. However, when included with nanoparticles, silicone oil can quickly diffuse into hair fibers due to its small size. This improves hair hydration, shine, and lubrication [42]. The use of nanomaterials to this formulation enhances component deposition in the hair and has a direct impact on amino acid synthesis. Keratin production is required to heal the cuticle and cortex. Nanomaterials have the potential to enhance the appearance of hair by improving interaction with the hair follicle and shaft, increasing the number of integrated active compounds that reach the target region. Encapsulating compounds within nanoparticles enhances penetration and permits previously insoluble molecules to be delivered [43]. The primary role of novel carriers such as liposomes, microemulsion, nanoemulsion, niosomes, and nanospheres is to help restore structure and shine to damaged cuticles, and make hair less brittle, non-greasy, and glossy. For instance, due to its softening and conditioning properties, the primary component of liposomes, phosphatidylcholine, has been applied in several formulations for products for both hair and skin care, including shampoo and conditioner. Due to its ability to encapsulate the active moiety and the fact that they are biodegradable, nontoxic, and biocompatible, liposomes are used in a variety of cosmeceuticals. In addition to being used in a range of applications as nanotechnology-based cosmeceuticals, including hair, nail care, and skin, dendrimers represent a novel class of macromolecular architecture. Shampoos, sunscreen, hair-styling gels, and anti-acne creams are just a few examples of the many cosmetic items that can benefit from dendrimers [44].

Hair Dye

In hair formulations alkalis or oxidation are the foundation, especially hair color solutions, and as many people have noticed, these processes leave hair thinner and dryer after use. Permanent hair dyes are manufactured from color precursors that hydrogen peroxide oxidizes on the hair surface; these redox reactions can be harmful to hair. Hair color products are made using a range of techniques and ingredients. [4]. As a result, researchers used nanotechnology to develop a non-harmful and natural hair surface engineering technology or technique. Instead of using permanent hair dyes, the cosmetics sector has shifted its focus to the creation of new colours and precursors. Nanotechnology has been used to colour hair since ancient Greek and Roman cultures were able to create quantum dots inside the hair shaft by blackening hair using a mixture of slaked lime, litharge, and water [46]. Nanomaterials when integrated into hair care products, they may enhance the benefits of active substances. The use of nanoparticles for the delivery of the drug into the hair follicle is an effective method. Compared to non-particle coloring, nanoparticles reach the hair follicles far deeper. Given how the hair follicles' surface is arranged, hair movement could serve as a pumping system or mechanism, driving the nanoparticles to penetrate into the hair follicles [47]. Furthermore, encasing dye in nanoparticle containers enables the water pigment to become more stable (similar to color-loaded clay nanotubes), which can then be used to create aqueous dispersions for hair.

Hair-styling Gels

Among the nanomaterials commonly used in hair-styling gels or products are dendrimers. Dendrimers are micellar nanostructures that are unimolecular and monodisperse. They are utilized in many cosmetic and personal care products, including hair shampoos, styling gels, anti-acne treatments, and sunscreens due to their excellent carrier properties [48]. Dendrimers contain both hydrophilic and hydrophobic molecules due to their properties [49]. These nanostructures have made their way into a broad range of cosmetic products: shampoos and hair styling products, [50]. Giroud et al. describe the incorporation of alumina, particularly boehmite or titania NPs, into different hair care product formulations to add volume and enable styling without binding or overstyling the individual hair strands or fibers. The formulations can be used for hair maintenance or hair style. They give the hair body without altering the way it feels, damaging the fibers, or making them stick together [19].

Benefits of the Application of Nanotechnology in Hair Care

Hair is a fundamental structure made up of simple uncomplicated filaments that provides protection from heat from either direct sunlight or any processes involved in hair care treatments. Moreover, it mirrors a person's social and relationship status, including features like youthful appearance, age, and lifestyle trends. Thus, it is considered as a key health indicator. However, what makes up the hair in reality are intricate structures that are involved in cellular differentiation, cellular proliferation, the life cycle, and diseases. Given that various substances can penetrate and work on several hair structural components, the frequent use of topical components may have a significant impact on the ultimate look of hair. Enter nanotechnology-based delivery for hair cosmesis. As reported by the cosmetics industry research, when nanotechnology is incorporated into hair care, it enhances the advantages of their active ingredients (AI) and this, in turn, improves hair cosmetics products [33, 34].

Innovations based on nanotechnology are intended to increase the integrity of cosmetic components, enhance the attractiveness of these cosmetic products, and concentrate AIs in structures that are the main point of interest for the controlled release and long-lasting effects of these agents. The use of nanoparticles to maintain hair health, shine, and silkiness has been the subject of extensive research [32]. With this, hair care and treatment have changed dramatically over time as a result of ongoing research into new formulations to try to suit the demand in the pharmaceutical and cosmetics sectors. While basic hair cosmesis practices like washing, colouring, and bleaching are targeted at cleansing, maintaining, and accessorising hair, newest hair care techniques are mostly concentrated on preventing hair fall or loss situations, bolstering hair cavity characteristics, and treating infestations in hair [35].

Currently, the most popular hair cosmetic goods are formulations for shampoos and conditioners, as well as items for styling hair, like straightening products and waving, formulations to prevent hair loss, and formulations for colouring and bleaching hair [15]. These cosmetic preparations are designed to enhance and care for hair, including washing and repairing it as well as promoting hair growth and changing its colour [37]. With regards to this, While dermocosmetic products that counter hair loss and anti-dandruff brands primarily concentrate on treatments that rely on active substances being absorbed into the scalp of the hair, shampoo, conditioner, and leave-on hair products are aimed at enhancing the appearance along the length of the hair. The effectiveness of the applied active compounds will depend on one of three possible paths. These are the intercellular, hair follicle, and lastly, the transcellular. Diffusion occurs in the intracellular pathway when chemicals move through the corneocyte surfaces, surrounded by lipid layers, and into the scalp's stratum corneum. Hair follicle pathway occurs by diffusion through follicular orifices reaching the scalp's deep region where capillaries

surrounding hair follicles can be found. Finally for the transcellular pathway, the penetration of the substances to the corneocytes and lipid layers to reach living cells is direct [33]. However, the follicular delivery of nanoparticles offers some advantages over traditional routes, such as improved skin absorption, increased penetration depth, and longer residence time, quick delivery to the skin and tissue targeting [35].

Due to their many uses, wide range of readily available preparations, and ease of access as well as manipulation, hair preparations as cosmetic or medicinal formulations, either for hair care embellishment or medical care reasons, have greatly expanded in popularity. [33, 38]. "ASTALIFT SCALP FOCUS" a product developed by FUJIFILM which aims for the development of hair care cosmetic products, aimed to improve the elasticity and reduce firmness of hair. This is achieved with the use of nanosized (80 nm) glycyrrhetic acid emulsion. Glycyrrhetic acid, widely used as an active ingredient for hair growth can only be used if formulated with high concentrations of ethanol. This, however, leads to the problem of dehydration and inflammation of the scalp proven through continuous usage of ethanol. Thus, nanosized glycyrrhetic acid emulsion was formulated as it could penetrate into the scalp without the aid of any ethanol. Many women who have hair issues as they age have an increased demand in recent years for anti-aging hair care solutions. Reduced bounce, resilience, and volume are common issues that result from aging-related scalp conditions such dryness and inflammation. In order to treat damaged hair effectively and to enhance the state of the scalp, it is necessary to infuse the scalp and hair with enough of the vital active components. As a result the product was a fully functional hair care product with an increased permeability and dispersion than the normal glycyrrhetic acid [39].

Cosmetic formulations with nano-based inclusions may improve optical qualities and exhibit biological action. This focuses the use of nanotechnology for compound delivery in hair care and medical treatments, which enhances compound efficacy and reduces compound toxicity or irritation, improves compound stability, controls compound release, reduces the amount of a compound required, enhances follicular and/or dermal permeation of hydrophilic/moderately lipophilic compounds, targets compound delivery to hair shaft and hair follicle, and maximizes interactions between hair fibers and the compound loaded with nanomaterials [40, 19].

Risks Associated with Nanotechnology

Risks of Nanomaterials

Researchers continue to issue warnings about the possible dangers of nanoparticles despite the development and widespread usage of nanotechnology and nanomaterials in cosmetics. Unwanted nanomaterial penetration and absorption through the skin and circulation have been documented in several studies. Any nanomaterial's unique characteristics that lead to the desired function or quality of the cosmetic product may also put the consumer in danger. [36]

Particles become more reactive as their size lowers because their surface area expands, this characteristic poses a risk for individuals using cosmetics that employ nanomaterials. When sufficiently in contact with a powerful ignition source and finely dispersed, several nanomaterials, such as silicon dioxide and titanium dioxide, have the potential to ignite and burst in the atmosphere.[41]

Risks of Nanoparticles in Cells

Nanoparticles of Zinc oxide, which are commonly employed in sunscreens, have shown neurotoxicity in the neural stem cells of mice [31]. After 24 hours, the assay showed that there was a dose-dependent toxicity present on the neural stem cell cultures, which showed apoptosis. The study used cultures of neural stem cells with zinc oxide nanoparticles.

Occupational Risks of Nanoparticles

The usage of nanomaterials in manufacturing is also linked to occupational dangers; workers may be exposed during manufacture, use, or even disposal of nanoparticles. Because nanoparticles are present in so many consumer products and because their use is expanding, consumers are more likely to be exposed to them. Inhalation is the most frequent method of exposure to nanoparticles in the air, according to the National Institute of Occupational Health and Safety. Nanomaterials can also enter the body accidentally through hand-to-mouth contact or voluntarily through intentional consumption [18]. In a study by Ryman-Rasmussen et. al, showed that within 24 hours of exposure, several nanomaterials have penetrating layers of pig skin. [51]

Environmental Risks of Nanoparticles

Nanomaterials can enter the environment through discharges into the water, air, and soil when they are produced, utilized, or disposed of. If these nanoparticles are antibacterial in nature and are released in sufficient quantities, they may potentially interfere with beneficial bacteria in sewage and

wastewater treatment plants and contaminate water that is intended for reuse. Nano-titanium dioxide, a substance used in personal care products, was shown to prevent bacteria from performing some biological functions after less than an hour of exposure, according to University of Toledo researchers. These findings suggest that these particles, which are released at municipal sewage treatment plants, may help cleanse wastewater by eradicating microorganisms vital to ecosystem function. [18].

Conclusion

The unique features exhibited by particles at a nanoscale account for nanotechnology's significant effect in the cosmetic arena. According to cosmetics industry research, nanoparticles can increase the advantages of active substances when incorporated into hair care products. Enhanced understanding of hair fiber composition and follicular targeting pathways is helpful in the creation of personalized cosmetic products and emerging technologies capable of improving hair cosmesis. Despite the fact that some experimental progress has been achieved, before nanotechnology is made generally available to customers for the improvement of several nanotechnology platforms for the delivery of hair care products, more research and a better understanding of toxicity are necessary. Nanotechnology, even with its given advantages in the cosmetic industry poses risks to different organisms in the environment, as well as occupational safety.

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