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Nanotechnology-Based Delivery for Skin/Personal Care Products: A Review

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A B S T R A C T

The field of cosmetic science has witnessed the evolution of cosmetic products from the conventional system to nanotechnology delivery system. The use of nanomaterials has brought a huge leap in the cosmetic industry, especially in the production of skin care and personal care products, because it offers the advantage of enhanced and improved product properties with regard to its aesthetic appeal, stability, controlled release of active ingredients, dispersibility, and skin penetration among others. This review paper focuses on the utilization of nanotechnology in the delivery of various skincare and personal care products. Specifically, it provides a synthesis of the main findings of all relevant publications about the different nanoparticles used in moisturizers, sunscreens, lip care and hair care products. Several studies have highlighted the benefits of nanoparticles incorporated in different forms of cosmetic preparations. Further study and a much greater understanding of its safety, effectiveness, and toxicity is vital before such innovation can be made widely available to the general public.

Keywords: hair care; lip care; moisturizers; sunscreens; nanotechnology; skincare; personal care

1. Introduction

The evolution of cosmetic products from the conventional system to nanotechnology has been an integral part of cosmetic science. Nanomaterials have been a huge breakthrough in the industry, especially in skincare and personal care products, due to the enhancement and improvement of their properties in terms of solubility, color, textural quality, skin penetration, stability of the ingredients, and controlled release of active ingredients [1,2]. In addition, they contain a larger surface area because of the reduced particle size. Thus, it aids in improving dispersibility, biological activity, absorption, and delivery of the product to the target organ, which is the skin [3,4]. These nanomaterials employed in cosmetic formulations, also known as nanocarriers, include liposomes, cubosomes, niosomes, dendrimers, solid lipid nanoparticles, nanostructured lipid carriers, nanoemulsions, and many more [1,3,5]. Their application towards cosmetic products is proven to be significant and many brands today already employ this type of novel approach.

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Cosmetic products have been widely used by consumers because of their increasing awareness of personal appearance, beauty, hygiene, and care. Furthermore, the impact of the COVID-19 pandemic on the consumers' perceptions and attitudes towards skincare and personal care products also caused a rise in consumer interest in these products [6]. This phenomenon can come from knowledge about skin conditions and self-confidence affected by the pandemic [6]. Due to increased demand and competition, companies would utilize more innovative strategies to manufacture their products for consumers, hence steering to nanotechnology.

Nanotechnology incorporated in cosmetics has now been highly regarded by companies and manufacturers due to its low production cost and enriched characteristics [3]. One of the most common cosmetic products utilized in nanotechnology include moisturizers, sunscreens, lip care, and hair care products. These products are commonly used by consumers because they can be used for different skin and hair conditions, protection against sun exposure, and enhancement of appearance [6]. Nanomaterials are extensively employed in these products. This review discusses how nanotechnology is applied to these types of cosmetic products and how these nanocosmetics can affect the current generation of skincare and personal care product consumers.

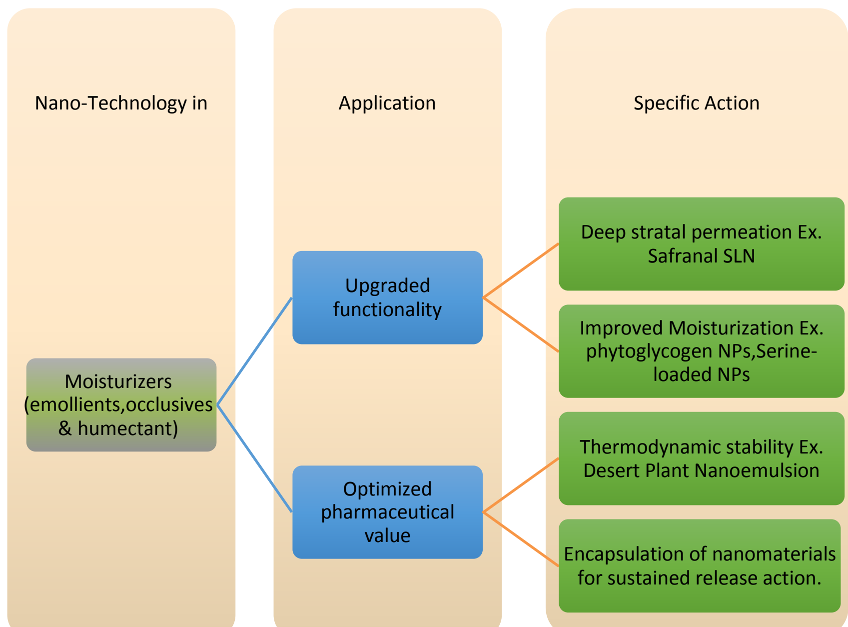

Fig. 1 Nanotechnology in Moisturizers

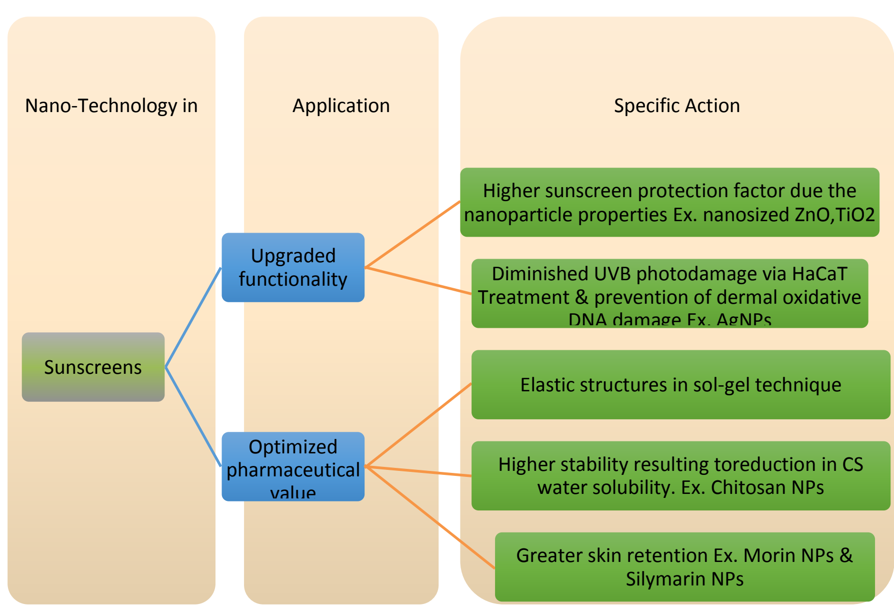

Figure 2. Nanotechnology in Sunscreens

2. Moisturizers

Skin moisturizers are one of the top consumers' skincare essentials which is in strong demand to enhance moisturizer synthesis. Consumers have different hydration needs that drive the development of moisturizers. There are a lot to consider when utilizing moisturizers such as age, race and even climate considerations. Appropriate skin water content is significant for the normal desquamation functions and water content has a strong impact on the skin's mechanical properties like softness, elasticity, plasticity and flexibility. Stratum corneum is the outer layer of the skin that regulates water loss and manages the water-holding properties. It contains hydrophobic components that hold water and on the other hand, the hydrophobic lipid matrix serves as a barrier to water loss. Thus, through these supplementary properties it influences the production of skin moisturizers where it pursues to have occlusive and humectant ingredients in the formulation that mimics the mechanism of skin natural water retention [7].

Emollients, occlusives, and humectants are commonly found in moisturizers. Combinations of occlusives and humectants improve skin's water-holding capacity. Additionally, the addition of certain emollients to moisturizers may increase the cosmetic quality and durability of the active components. Skin dryness is eased synergistically when glycerol and occlusives are combined. Cosmetic emulsions are the most common formulation, with the majority being lotions (oil-in-water emulsions) or creams (water-in-oil emulsions) and thus most moisturizers having nanoparticles as the key ingredient are commonly formulated through nanoemulsions. Some active substances are delivered and stabilized using complex emulsions (e.g., oil-in-water-in-oil, oleaginous mixes, serums, gels, sprays, and milks) [8].

Table 1 - Comparison Between the Characteristics of Conventional and Nano-Based Moisturizers.

CHARACTERISTICS	CONVENTIONAL	NANO-BASED TECHNOLOGY
Particle Size	1 to 20 mm [9]	1 and 100 nm [10]
Phases	Biphasic [9]	Monophasic [9]
Viscosity	High [9]	Low [9]
Penetrability	Conventional moisturizers barely sit on the skin [11] but if added with humectants, it enables deeper penetrability to reduce dry skin symptoms [12]	Deepest layers of the stratum corneum [13]
Stability	Thermodynamically unstable, Kinetically Stable [9]	Thermodynamically unstable, Kinetically Stable/Metastable [9]
Moisturization	Average moisturizing effect. Added effect will also depend on the other components of the formulation [8]	Prolonged moisturizing effect [4]

2.1 Nanoparticles Used in Moisturizers

Particles with 1-100 nm diameter are considered to be nanomaterial. It finishes the introduction by explaining how moisturizers help in times of inflammation. Moisturizers have been thought to improve barrier function in inflammatory conditions by providing occlusion and trapping of allergens and other irritant molecules. It also said how nanoparticulate formations are superior in terms of traditional formulations in their ability to minimize water loss and prevent irritation. Nanoparticulate formulations of moisturizers also had an increased effect in lessening the appearance of wrinkles. Nanoparticles give a variety of desirable properties when used in topical applications. Their small size allows for better penetration past most physiological barriers, especially the epidermal barrier. The small size of nanoparticles also allows for a higher surface area to volume ratio, allowing for greater exposure of active molecules per dose administered. Encapsulation by nanomaterials also allows for sustained release, and provides a new method for delivering unstable or insoluble compounds These properties of nanomaterials are also modifiable—particle size can be altered to control penetration, pore size to control release, surface molecules added for targeting to specific tissues—allowing monotherapies to be tailored for distinct uses [10].

2.1.1 Phytoglycogen Nanoparticles

Phytoglycogen is a variety of non-GMO sweet corn that is a natural polysaccharide produced in high quantities that is also found in other plants. This polysaccharide produces a monodisperse nanoparticle with 35 nm diameter. Phytoglycogen is composed of glucose monosaccharide units such as cellulose, starches and dextran. Moreover, it is known to be safe as it is a natural botanical extract which is produced by nature as nano-sized particles, water-soluble, not biopersistent and voluntarily degrades into simple sucrose in the body and in the environment. The unique structure of phytoglycogen creates a highly branched internal environment of hydrophilic polysaccharide chains that associate with hydration water thus, giving rise to properties including low viscosity, high water retention, film-forming capabilities and rheological modifying. In the study, the properties of stratum corneum is a combination of content of water and hydrophilic materials. According to the study, plasticizing the stratum corneum using humectant improves the mechanical properties of the skin that retain water [7].

The investigation of phytoglycogen's water retention using infrared spectroscopy examines the water molecules hydrogen bonding structure sorbed by films of polysaccharides, phytoglycogen and HA. The number at which water absorbs infrared spectroscopy lights depends on its degree of hydrogen bonds. The stronger the hydrogen bonding, the lower the IR frequency assimilated by the water molecules. Additionally, in this investigation, there is a connection between the chain architecture of polysaccharides and composition of the water hydrogen bond. It was also found out that the highly-branch dendrimeric composition of phytoglycogen enhances the water connectivity. The result recommended that the phytoglycogendendrimeric structure is responsible for its water retention properties; however, there is a limit to the quantity of water that can be absorbed by the particles. Also, by utilizing quasielastic neutron scattering (QENS) and small-angle neutron scattering (SANS) hydration of phytoglycogen in aqueous dispersion has been studied and for the result the dry molecular wt which is the polysaccharide without water was found to be 4.16 x 10 g/mol, on the other hand 6 the polysaccharide with water was found to be 14.7 x 10 g/mol. Thus, the strong interaction of 6 water and phytoglycogen is assigned to its closely packed and highly branched chain architecture. Also, this strong interaction of both water and phytoglycogen is consistent with IR investigation [7].

2.1.2 Safranal-Loaded Solid Lipid Nanoparticles

Solid Lipid Nanoparticles (SLN) formulations have been studied as a potential drug delivery mechanism by groups of researchers throughout the last decade. Novel dosage forms such as polymeric micro/nanoparticles, lipid emulsions, and liposomes have significant benefits over traditional drug delivery systems. SLN can also help these systems overcome their inherent limits. Because of its permeability-enhancing qualities, SLN has lately been employed as a transdermal drug carrier; it raises skin water content, inhibits UV rays, and possesses occlusive effects. Safranal incorporated with SLN (SLN-safranal) could be a promising way to boost safranal's efficacy. The skin hydration of produced SLN-safranal was assessed in this study utilizing the corneometer in vivo method [14].

The skin's moisture content was assessed using a chronometer to measure skin hydration values. After using SLN-safranal and free-SLN formulations, skin moisture improved. As evidenced by the qualities of free-SLN formulations, the SLN-safranal formulations improved skin moisture even more [14].

2.1.3 Opuntia ficus-indica (L.) Mill Extract Nanoemulsion

Desert plant Opuntia ficus-indica (L.) Mill includes phenolic components (kaempferol and quercetin) and carbohydrates (galacturonic acid, glucose, rhamnose, and arabinose). Using hydro glycolic extract from Opuntia ficus-indica (L.) Mill, this work produces and describes an O/W nanoemulsion and assesses its thermal stability and moisturizing properties [15].

Nanotechnological products have better qualities than other products. Occurrence of a moisturizing effect in traditional emulsions with Opuntia ficus-indica (L.) In the investigation, nanoemulsions outperformed traditional emulsions using the same extract in moisturizing ability. Morganti attributes this to the smaller droplet size of nanoemulsions, which allows more homogeneous deposition on the skin and greater penetration through skin layers. Also, this research employed a commercial moisturizer as a positive control. In addition to its humectant characteristics, Opuntia ficus-indica (L.) Mill extract, like freeze-dried aloe vera extract, has no occlusive properties. Gaspar et al. showed comparable outcomes with moisturizer formulations, including Saccharomyces cerevisiae extract and vitamins. Although the formulation increased stratum corneum hydration, the TEWL did not alter, indicating that it also has a moisturizing effect through a humectant mechanism [15].

2.1.4 Serine-Loaded Solid Lipid Nanoparticlesand Polysaccharide-Rich Extract of RootPhragmites communis

Serine-loaded SLN evidently shows to be an effective nano-sized carrier which facilitates the transport of hydrophilic compounds like serine across all layers of the skin surfaceObservation periods were done from 0 to 3 hours time. Upon application of the hydrogel base, increased conductance values of the skin were observed and assessed. As serine is considered to be one of the most abundant components found in NMF because of its ability to effectively bind water molecules caused by its hygroscopic property, it is quite easier to incorporate and observe. Hydrogels containing 0.25% RRE, and 3 and 5% serineSLN significantly increased moisture contents in the skin as compared to the blank hydrogel devoid of RRE and serine-SLN [16].

Having that SLN is evidently shown to be an effective nano-sized carrier which facilitates the transport of hydrophilic compounds like serine across all layers of the skin surface. Due to the combined effect of S-SLN and RRE,the moisturizers were incorporated into the hydrogel baseshaving that both were able to assist the moisturization effect caused by serine and liposomal serine. This is largely due to their ability to entrap large amounts of water molecules in their networks to provide an immediate aqueous and water-rich environment on the skin. Only at both 3% and 5% serine-SLN were observed to have improvement in skin moisturization. In terms of sheer rate which affects viscosity, hydrogels incorporated with serine-SLN, increased shear rate gradually reduced the viscosity of the formulations. Upon investigation on any observed viscosity changes, it could be assumed that the greatest viscosity demonstrated by 10% serine-SLN hydrogel might delay the liberation of serine from SLN or the movement of serine within the hydrogel bases and these might be the main reasons for the decreased moisturization effect of the hydrogel with 10% serine-SLN. Therefore, viscosity decreases with increased levels of RRE. The increasing levels of serine-SLN in hydrogels seem to have shown the greatest amount of dependency on shear stress applied to flow as observed with the higher yield stress for the hydrogel with 0.25% RRE and 7% serine-SLN. Through such data, the hydrogel formulation with 0.25% RRE and 7% serine-SLN was more resistant to spread or even apply to the skin, which makes the application most likely to not be achieved hence the effort made through the use of a nano-size particle transporter to deliver the hydrogel formulation on the skin in a manner that it is reproducible [16].

3. Sunscreens

Excessive sun exposure is one of the leading causes of skin cancer. Sunscreens, for example, are designed to protect our skin from the harmful effects of

UV rays. In a study by Shi et al (2012), it focuses on the nanoparticles that are used to transport sunscreen because the effects of sunscreen are dependent not only on the physicochemical features but also on the carrier utilized. Nanoparticles utilized as a carrier system for sunscreen delivery have shown promise in creams, sprays, and gels. In addition, nanoparticles protect organic filters from chemical deterioration since they encase them inside the core. Nanoparticles also act as carriers and reduce light by adsorption and scattering [17].

Table 2 - Comparison Between the Characteristics of Conventional and Nano-Based Sunscreens

CHARACTERISTICS	CONVENTIONAL	NANO-BASED TECHNOLOGY
Sun Protective Factor (SPF)	The SPF of a sunscreen lotion containing conventional ZnO particles is 2.90 and 1.29 for TiO2, which is lower than the SPF of nano-based particles, 3.65 for ZnO nanoparticles and 4.93 for TiO2 nanoparticles [18].	The SPF of sunscreen creams containing ZnO nanoparticles and TiO2 nanoparticles was found to be higher than conventional sunscreen creams because of the influence of particle size reduction, which is from micro to nano [18].
Transparency	Commercial sunscreens produce whitish residue when applied to a surface [19]. It is also usually cloudy or misty [20].	Nanosized ZnO and TiO2 particles improve transparency due to the repulsion of negative charges that surround the titanium nanoparticles [19]. The natural opaqueness of these components is eliminated without reducing their UV blocking efficacy [20].
Skin permeability	A great number of conventional sunscreens are available on the market. However, the permeability barrier of the skin by intracellular lipids limits the permeation of UV-filters into the skin [21].	The nano-based sunscreen formulation is an advanced system of delivery of active sunscreen agents deep into the skin that controls drug release, emphasizing their safety and efficacy [21].
Greasiness	Conventional sunscreen components like iron, titanium, and zinc are difficult to suspend in nongreasy carriers in bulk form [22].	Nano-based sunscreen allows chemicals to suspend greaselessly because of their greater surface-to-volume ratio and the presence of polar oxygen on their exterior, making it a visually appealing carrier [22].

3.1 Inorganic Nanoparticles used in Sunscreens

Minerals like zinc oxide (ZnO) and titanium dioxide (TiO2) are often used as inorganic physical sun blockers. Only in the last ten years have sunscreens with both UVB and UVA filters been created. The natural density of these nanoparticle sunscreen components has been reduced without compromising their UV blocking performance by using nanosized ZnO and TiO2 particles. Organic substances that exclusively absorb ultraviolet rays are not recommended [20].

3.1.1 Silver Nanoparticles

One of the most prominent causes of UVB radiation-induced photodamage to epidermal DNA is its carcinogenic effect on skin cells. The production of cyclobutane–pyrimidine dimers (CPDs) and 6–4 photoproducts (6–4PPs) lesions is a common biological outcome of UVB exposure. On UVB-irradiated HaCaT cells, pretreatment with Ag-NPs provided significant protection, whereas ZnO and TiO2-NPs were mostly ineffective. The production of reactive oxygen species (ROS) by UVB works as a potent oxidant, causing oxidative DNA damage. When HaCaT cells were treated with Ag-NPs at a concentration of 2 g/mL, there was no increase in ROS formation. The ROS-inducing impact of ZnO and TiO2-NBP has been found. It resulted in higher ROS production and decreased antioxidant enzyme enzymatic activity, which could be related to their phototoxic synergy. By activating anti-oxidant enzymes, Ag-NPs protect HaCaT cells from UVB-induced direct DNA damage and oxidative DNA damage. ZnO-and TiO2-NP failed to protect cells from the damaging effects of UVB and created an oxidant environment. These nanoparticles could be a good replacement for currently used active ingredients in commercially available sunscreen creams. Overall, according to the findings, Ag-NPs outperform TiO2-and ZnO-NPs in shielding human skin cells from the harmful effects of UVB [23].

3.1.2 Titanium dioxide Nanoparticles

Different approaches have been used to generate TiO2 nanoparticles that have been changed and are of a desired size. The sol-gel technique, which involves hydrolysis followed by condensation reactions, uses alkoxides soluble in organic solvents as a precursor. In this approach, p-toluene sulfonic acid (PTSH) has been shown to be a great option for surface modification of TiO3 nanoparticles, allowing for the manipulation of size, form, and aggregation. PTSH can also be used to prevent the aggregation of nanoparticles and allow for clear and extremely concentrated suspensions. The clear sunscreen with wide photoprotection derived from surface-modified TiO2 nanoparticles synthesized by the sol-gel technique showed promising features. Storage modules were higher than loss modulus in the gel-based preparations, indicating the predominance of the centralized elastic structure [19].

3.1.3 Zinc oxide Nanoparticles

Zinc oxide (ZnO) nanoparticles (NPs) are commonly used in the cosmetic industry, accounting for 70% of all ZnO NPs used in personal care products, such as sunscreens, to filter harmful ultraviolet sunlight radiation (UVA; 320–400 nm) and UVB (290–320 nm). ZnO NPs (30 nm) are commonly used in sunscreen formulations because they are aesthetically pleasing, appear transparent on the skin, and are effective at reflecting UV absorption. Moreover, this study is the first to use non-invasive multiphoton imaging to demonstrate that zinc oxide does not penetrate the skin's outermost layer, the stratum corneum (SC), a finding that was confirmed in subsequent studies. Aggregation of ZnO NPs in ultra-pure MQ water is due to the solvent's low ionic strength and a lack of stabilizing organic matter. In CCT, aggregation is reduced, potentially due to this solvent's increased viscosity, which inhibits diffusion and collisions. Increasing particle size through aggregation would likely reduce the dissolution of ionic zinc species. HaCaT cells in DMEM+10% FBS were handled for 24 hours with blank, low (5 g/mL) and high (50 g/L) concentrations of 67ZnO NPs, before being ultracentrifuged to extract cells and proteins. Assayed supernatants contained Zn2+ and zinc species bound to low molecular weight ligands. Based on the fluorescent intensities of the zinc sensor ZP1 in the complete cell culture medium, a qualitative evaluation of ClaZn revealed a monotonic increase in the concentration of labile zinc versus the dosed amount of 67ZnO, supporting the previously reported elevated cytotoxicity versus concentration of zinc oxide nanoparticle [24].

3.2 Safety and Effectiveness of Titanium dioxide and Zinc oxide

The study by Smijs and Pavel (2011) on the safety and effectiveness of titanium dioxide and zinc oxide highlighted thatsunscreens should provide protection against the adverse effects of both UVB and UVA radiation. The effectiveness of these compounds is that zinc oxide is recognized as one of the better sunscreen components since it not only filters both UVA and UVB rays, which cause severe burns, skin irritation, and skin problems, but it is also entirely photostable and resistant to water. Titanium dioxide is also more efficient at UVB. The combination of these particles provides excellent UV protection. In terms of safety, according to the International Agency for Cancer Research (IARC), TiO2 has been categorized as an IARC Group 2B carcinogen because of its human carcinogenicity. ZnO, on the other hand, when used, is "generally recognized as safe" by the FDA as a UV filter in accordance with cosmetics regulations. Several sunscreen components are usually regarded as safe since they do not seep into the bloodstream. These include zinc oxide and titanium dioxide, both of which are used in sunscreens. However, NPs from the formulations can permeate into the deepest human SC layer, next to viable epidermal cells, but they typically stay in the upper section. The type of TiO2 and ZnO nanoparticle coating and formulation in sunscreen products are useful techniques in mitigating the dangers of NP sunscreens. Nanoparticle sunscreen production still demands extreme caution. That could be improved through joint coordination with research institutions and sunscreen manufacturers [20].

3.3 Organic Nanoparticles used in Sunscreens

Scientists are primarily focusing on herbal formulations because of the toxicity of synthetic molecules presently available in sunscreen formulations that primarily contain chemicals or synthetic molecules. The researchers enunciated that the herbs obtain better action than synthetic products based on the studies carried out. An herbal formulation is absorbed into a deeper layer and acts more effectively at lower concentrations [25].

3.3.1 Chitosan Nanoparticles

In the study of Ntohogian et al. (2018), the researchers evaluated the preparation of sunscreen using chitosan nanoparticles with annatto, ultrafiltrated (UF) annatto, saffron, and ultrafiltrated saffron. The result of the study revealed that chitosan (CS) nanoparticles are safe to employ in biomedicine and cosmetics, according to the study. The creation of CS nanoparticles during ionotropic gelation is mostly dependent on the ionic interaction of CS with tripolyphosphate (TPP), which finally leads to a reduction in CS water solubility. It also showed that CS: TPP ratios ranging from 2:1 to 5:1 can produce excellent nanoparticles with a low polydispersity index. Moreover, it was stated in the study that all of the studied sunscreen agents (annatto, UF annatto, saffron, and UF saffron) were used to make CS-based nanoparticles. According to SEM analyses, the produced nanoparticles had an irregular shape, and their sizes ranged from 150 to 500 nm. Furthermore, XRD study revealed amorphous dispersion in annatto and UF annatto nanoparticles and crystalline dispersion in saffron and UF saffron nanoparticles, while FTIR analysis revealed H-bond interactions. Sunscreen emulsions made from the resulting CS–sunscreen agent nanoparticles had high storage stability in terms of pH and viscosity for up to 90 days at room temperature, while minimal sunscreen protection was determined with SPF values ranging from 2.15 to 4.85 in all cases [26].

3.3.2 Morin Nanoparticles

The study by Shetty et al (2015) stated that using flavonoid morin as a research tool was an important part of this work. Antioxidant and UVR protection are both provided by this substance. Because of this, a polymeric nanoparticle loaded with morin and nano ZnO and TiO2 was designed to increase penetration. Morin is an epidermal layer poly(D,L-lactide-co glycolide). Various formulations were explored to obtain reduced mean particle size, polydispersity index, greater zeta potential, and drug-entrapment efficiency. This formulation tested consisted of 2.5 mg of morin, 25 mg of PLGA, and 1% PVA solution homogenized at 16, 000 rpm for 10 minutes with 80 amplitude sonication parameters to achieve a wattage output of 25/cm2. Morin undergoes partial amorphization due to a small drop in melting point. Morin is found to be more effective than quercetin (standard) at scavenging DPPH. The slower diffusion of morin from the NPS could explain the higher IC50 value found when NPs develop. The Morin NPs-containing creams had a greater skin retention rate. This significant penetration could be attributed to NPs' capacity to permeate the skin more deeply. Following application of the tested creams, the control animal showed no indications of erythema or edema. This shows that the creams were able to scavenge the reactive oxygen species produced by UV exposure. The SC5 cream (containing physical sunscreen agents and morin NPS) and the SC8 cream performed the best in terms of properties out of the eight formulations tested. This research highlights the possible application of morin in sunscreen goods as well as how it might be improved through the use of nanotechnology [27].

3.3.3 Silymarin Nanoparticles

According to the study by Netto and Jose (2017), silymarin is a plant-derived polyphenol from milk thistle and it is recognized as hepatoprotective. When applied topically, it prevents UV light from penetrating the deeper layers of the skin. Because of their uniform size, low surface area, and high drug loading capacity, solid lipid nanoparticles are becoming more popular. Silymarin is a plant-derived polyphenol from milk thistle and it is recognized as hepatoprotective. When applied topically, it prevents UV light from penetrating the deeper layers of the skin. Because of their uniform size, low surface area, and high drug loading capacity, solid lipid nanoparticles are becoming more popular. Silymarin solid lipid nanoparticles were successfully produced, and the dispersions were integrated into SPF cream for topical application to the skin. Sun protection factor determination in vitro and in vivo revealed SPFs of 13.80 and 14.1, respectively. The findings also revealed that the solid lipid nanoparticles could be good potential photoprotective carrier agents [25].

3.4 Nanoparticle-based Sunscreen Cream containing Aloe Vera

Sunscreens today are mostly made up of chemicals and other organic components that might potentially disrupt the skin's natural biota. Herbal formulations have been studied since they are known to have higher photoprotective potential with fewer or no side effects. Aloe vera is a plant that has potential aesthetic and medicinal use. The stability and permeability efficiency of this plant candidate can be considerably increased by synthesizing it into solid lipid nanoparticles (SLN). Based on the entire tests conducted, the sunscreen cream containing Aloe vera was found to be comparable to other sunscreens sold on the market. The result of in vitro SPF was determined to be the highest SPF value within the range of 14.6–16.9. This indicates that the formulation is effective in delaying the penetration of ultraviolet radiation to the skin. The photoprotective agent Aloe vera SLN was prepared by adding glyceryl monostearate (lipid) and Tween 80 (surfactant) to the composition [28].

4. Lip Care

Lip care products are designed to smoothen the skin, provide protection, and also hydrate the lips [29]. Lipstick, lip balm, lip gloss, and lip volumizer are examples of nano cosmeceutical lip care products. Lip gloss and lipstick can contain a variety of nanoparticles that soften the lips by preventing transepidermal water loss and preventing pigments from migrating from the lips, which in turn helps maintain the color of the lips for a longer period of time [29,30]. In fact, a study about the use of nanotechnology in lip care applications argues that nanotechnology has a place in lip care, specifically lipstick. As a result, it promotes the controlled release of active substances and shields them from external agents while they are contained within nanocarriers [5]. Meanwhile, lip volumizer with liposomes boosts lip volume, moisturizes and defines the lip, and smooths out wrinkles in the lip contour [29]. Currently, nano-sized synthetic and metal particles are employed for lip protection and color enhancement. These products stay longer and are more uniform. Using nanometal particles improves pigment distribution across the lips, increasing protection. Lips are the most sensitive skin type, therefore use caution with synthetic and metallic nanoparticles [31].

4.1 Nanoparticles Used in Lip Care Products

4.1.1 Dendrimer

The dendrimer structure has assisted in boosting the overall loading and skin penetration of resveratrol (renowned for its anti-oxidant and anti-aging characteristics), which has contributed to the product's eventual scale-up and commercialization [29].

4.1.2 Liposome

Liposomes can transport both hydrophobic and hydrophilic substances. Their size ranges from 20nm to several micrometers, and their structure can be multilamellar or unilamellar. Because of its softening and conditioning effects, phosphatidylcholine, one of the key constituents in liposomes, is extensively utilized in skincare products. Liposomes have been developed that allow for the sustained transport of substances into cells, making them a perfect choice for the administration of vitamins and other compounds to repair the epidermis. They've also been used to help those with hair loss. Skincare products containing empty or moisture-loaded liposomes minimize transdermal water loss and are effective in treating dry skin. They also improve lipid and water delivery to the stratum corneum [29].

4.1.3 Nanocrystals

Nanocrystals of poorly soluble medications can also be used in cosmetics, where they have a high penetrating power when applied to the skin. The two nanocrystal antioxidants rutin and hesperidin are two of the newer products on the market that are poorly soluble plant glycoside antioxidants that could not previously be utilized topically. They become dermally accessible after being manufactured as nanocrystals, as determined by antioxidant action. Nanocrystals can be used in creams, and liposomal dispersions in cosmetic formulations such as lipsticks, lip balms and other lip care products [29].

4.1.4 Nanogold and Nanosilver

Antibacterial and antifungal properties of silver and gold nanoparticles have been examined. These particles are commonly found in cosmeceutical products such as deodorant, face packs, and anti-aging creams. When it comes to the application of such nanoparticles in lip products, a patent is held by the Korea Research Institute of Bioscience and Biotechnology describing the creation of pigments possessing a wide range of hues by blending in different compositional ratios and whose color can be sustained for an extended duration, all of which are possible with the use of gold or silver nanoparticles [4, 32].

4.1.5 Niosome

The capacity of niosomes to boost the stability of entrapped pharmaceuticals, improve the bioavailability of poorly absorbed substances, and improve skin penetration are all advantages of employing them in cosmetic and skin care applications which is very beneficial when niosomes are implied in lip care products to extensively create maximum penetration of necessary vitamins and minerals in the delicate lining of the lips [29].

4.1.6 Silica

An example of a nanoparticle is the silica which produces a uniform distribution of pigment and results in better-looking lips without fine lines. Silica Lipsticks with nanoparticles increase uniformity pigmentation distribution. They work by preventing colours from spreading or leaking into the delicate lip line [4].

4.2 Nanotechnology in Phyto-based Lip Products

Coconut oil, curcumin, and other bioactive ingredients with improved protective activity are commonly employed in lip care products on a macro and micro level. It has recently been discovered that plant betalains, a novel dietary colored indole pigment, may be extracted and encapsulated to improve storage stability and uses. Bixa orellana was used to color lip jelly and had better organoleptic characteristics. Propolis was also used to create a new lipstick. But nanotechnology in phyto-based lipstick creation is still in its infancy [31].

4.3 Safety of Nanoparticles Used in Lip Care Products

Nanoparticles employed in cosmetic products can be hazardous. Their toxicity is highly dependent on various factors, including their surface qualities, coating, shape, size, and ability to aggregate, all of which may be altered and managed during the manufacturing process. Toxicological studies had been conducted on the potential of nanoparticles for skin penetration, resulting in toxicity [33].

Nanoparticles can enter the body through unintentional or purposeful hand-to-mouth transfer. Lipsticks, lip balms, lip gloss, and other products for lip application might contain nanoparticles [5]. Such cosmetic products can cause systemic toxicity if ingested. The harmful effects are determined by a variety of elements; some are connected to the active components' formulation features, such as surface area, coating materials, particle size, and aggregation propensity, while others are related to the chemical composition of the active ingredient. The risk could be increased if the nanostructure has a surface that matches the organ. In general, increasing the ratio of surface area to volume increases chemical and biological reactivity [34].

5. Hair Care

Hair is an important indicator of health. It is composed of a hair shaft and a root surrounded by a hair follicle with a bulb in its end. The cortex is responsible for strength, elasticity, texture and appearance and it is coated by the cuticle that is composed of keratin and functions as a protective barrier [35]. Although hair is not a vital organ, it can be an indicator of one's health and have a significant impact on one's appearance. A variety of conditions, such as androgenic alopecia, hirsutism, and hair color loss, can have a significant impact on patients' quality of life, evoking cosmetic concerns as well as loss of self-esteem, feelings of social inadequacy, and helplessness. Hair quality is regarded as a significant indicator of health. Brittle hair, for example, could indicate thyroid disease or nutritional deficiency, while "dry scalp" could indicate a primary skin disease ranging from psoriasis to tinea capitis, and thinning hair could indicate hormonal imbalances. Given the importance of hair to one's quality of life, it's no surprise that people try to change their hair for a variety of reasons [36].

Table 3 - Comparison Between the Characteristics of Conventional and Nano-Based Hair Care Products

CHARACTERISTICS	CONVENTIONAL	NANO-BASED TECHNOLOGY
Hair Strength	Silicone is traditionally used in shampoos because of its hydrophobicproperty.However, silicone will build on the scalp and doesn't penetrate into the hair when you wash your hair regularly unlike the nano-based silicone [36].	Due to its small size, nano-based silicone oil can quickly disperse into hair fibers when integrated with nanoparticles. This results in enhanced hair hydration, shine, and lubrication, which contributes to increased hair strength [36].
Coating Capacity	Cocodiethanolamide, for example, does help disseminate the detergent throughout the hair and scalp and associates good foaming with effectiveness in washing but has nothing to do with cleansing [37].	Lipid nanoparticles filled with MXD are further emulsified with hydrofluoroalkane (HFA) and pluronic L62D surfactant to make foams that release MXD from the nanoparticles when applied to the skin [38].
Cleansing Capacity	Anionic detergents are particularly good in	Nanomaterials like silver nanoparticles are used

	eliminating sebum from the scalp and hair. Anionic detergents are most often utilized surfactants in basic washing shampoo and are the most popular surfactants used in the market [39].	in shampoos because they kill bacteria well. Silver nanoparticles are not toxic to animal cells, but they are highly toxic to bacteria [40].
Conditioning Capacity	Cationic polymers can play an essential role in supplying conditioning effects in shampoo formulations. Polyquaternium 44 is a good example of this component which on wet hair, it has the best conditioning effects without sacrificing removability [41].	Derived from the silkworm, Seracin as a cationic nanoparticle,is being applied as a conditioning agent and it has been shown to be effective in mending damaged cuticles and restoring shine and texture [36].
Anti-Dandruff properties	Zinc pyrithione (ZPT) is the most commonly used component in dandruff treatment. This fungistatic agent fights dandruff by preventing Malassezia species from regrowing [42].	In contrast to their macro scale counterparts, nanometer-sized metallic particles have distinct and significantly changed physical, chemical, and biological properties [43].

5.1 Nanoparticles Used in Hair Care

Nanomaterials have been found in almost every personal hair care product on the market, according to research. Nanomaterials have been added to shampoos to increase resident contact time with the scalp and hair follicle, thus enabling the active ingredients to form a protective film and seal moisture within the cuticles (i.e., preventing transfollicular water loss). This improves the moisture, gloss, and lubrication of the hair. This formulation has the advantage of not destroying the cuticle of the hair fibers, but rather allowing penetration into the hydro-lipid emulsion layer due to its nanosize. Conditioning, as opposed to shampooing, is responsible for reintroducing the materials required for proper growth, texture, and health. Serafin, a silkworm-derived cationic nanoparticle, has been found to be effective in repairing damaged cuticles and restoring gloss and texture in conditioning agents [36].

5.1.1 Clay Nanotubes

It can be used in cosmetic applications through self-assembly. The selectivity of its lumen loading and sustained-release of active dyes can be used as an advantage for self-assembly on the hair surface. The coating process of drug or dye-containing nanotubes containing drugs or dyes for hair coloring produces a stable 2-3 µm thick layer around the cuticle flaps. Also, the loading of clay nanotubes may be performed from any solution since halloysite-encapsulated dye may be soluble in water or organic solvents. Furthermore, making use of natural dye in loading the halloysite lumen is applicable in a spectrum of hair types and is found to be less damaging and nontoxic to hair and skin. However, it is important to note that the amount of halloysite loading is restricted to 10 vol.% of the lumen since some dye may be absorbed outside and this may change the physical-chemistry of the self-assembly. If there may be leakage during 10-15 h of the halloysite nanotubes loaded with dyes, the dye will still stay on the hair and thus preserve the color [35].

5.1.2 Graphene-based nanosheets

Carbon materials that also showed promising results in hair dyeing. When mixed with chitosan, the mixture yields color nanoformulations that are toxic-free in dyeing light colored-hair with dark shades (black to brown). This formulation also showed capabilities in resisting multiple shampoos and as an antistatic and heat dissipator. Moreover, the synthesis of chemically functionalized carbon nanotubes (CNT) used in coloring hair, eyebrows or eyelashes follows well-defined steps: cover the target surface by a polymeric layer followed by contact with the chemically functionalized CNT for the first color layer then repeated cycles reinforce the final color [35].

5.1.3 Clay halloysite nanotubes

Clay halloysite nanotubes are used in drug-delivery systems that are designed to be slow and sustained release and localized on the hair in order to be effective in eliminating infestation such as lice and other hair and scalp problems. The result of the in vivo test conducted in nematodes through-loading permethrin in nanotubes showed that it increased biocidal affect up to 85%. On the other hand, alopecia was also addressed by preparing the minoxidil-loaded halloysite nanotubes similarly to permethrin-loaded but making use of methanol as the solvent. Results revealed that a slow-release strategy is developed for topical hair surface coating with anti-hair loss agents. Hence, clay halloysite nanotubes can be utilized in delivering both hair color formulation and drug to the hair through loaded nanotubes [35].

5.1.4 Cationic nanoemulsions

Cationic emulsions (emulsions with droplet diameters less than 100 nm) significantly improved dry hair, even after multiple shampooings. The emulsion made hair look shinier, less brittle, and less greasy. Another compound containing oxides, hydroxides, carbonates, silicates, and phosphate nanoparticles was able to control hair grease. Finally, both in vitro and in vivo, the use of zinc and chitin nanofibril complexes reduced hair flakes (as measured by the corneocyte count) and sebum (as measured by milligrams of superficial lipids per square centimeter of skin surface) [35].

5.2 Hair Conditions

5.2.1 Frontal fibrosing alopecia (FFA)

This condition was first identified in 1994 as a type of cicatricial alopecia that primarily affects postmenopausal women. Sun exposure, topical allergens, foods, toxins, and trauma are all potential environmental triggers. Several hypotheses regarding pathogenesis have been proposed, including T-cell mediated allergic reactions, suppression of sunlight's anti-inflammatory effect, endocrine effects, and oxidative damage [44].

Results showed that the use of facial and hair cosmetics revealed a tendency for patients with FFA to use more facial leave-on products and sunscreens, but the differences were not statistically significant. There were no significant differences between the patients and the controls. Both groups' hair shafts appeared normal, with a cylindrical shape, regular contour, and uniform pigmentation. The EDX analysis revealed no significant differences between groups. Oxygen, sulfur, nitrogen, chlorine, calcium, sodium, potassium, and copper were among the elements studied and compared. Both patients and controls were found to have NPs. Chlorine, calcium, Ti, sodium, silicon, potassium, magnesium, iron, aluminum, and copper were among the elements found in the particles. In FFA patients, the number of particles containing Ti, chlorine, silicon, magnesium, and iron was significantly higher. Ti NPs were found in hair shafts from the anterior scalp of 100% of FFA patients and 80% of controls, with a median number 8.6 times higher in FFA patients [44].

5.2.2 Androgenetic alopecia

Androgenetic alopecia, which is the most common type of human hair loss, affecting roughly half of adult men by the age of 50 [39]. It develops as a result of a shortening of the anagen phase, resulting in increased hair loss and the transformation of terminal to vellus follicles. The follicular absorption strategy may be useful in treating these abnormalities as well. Follicular targeting can deliver topically applied substances to the sebaceous glands, making it a promising approach for topical treatment of sebaceous gland dysfunctions such as acne, seborrhoeic eczema, and rosacea [48]. Drug permeability through the keratin layer is slow due to follicular pores being blocked by horny and sebum plugs. Nanotechnology has emerged as a promising drug delivery system, allowing for greater permeation into hair pores and longer-lasting effects. Fullerene nanomaterials were found to be capable of increasing the likelihood of new hair growth and inducing formation of new hair follicle within the dermis of murine and human skin [36].

5.2.3 Appendage diseases

Study shows that dermatological diseases can be treated using follicular delivery. Topical delivery of drugs or nanoparticles that selectively target hair follicles is of interest in the treatment of some skin disorders, particularly appendage diseases [45].

5.4 Safety Concerns on the Use of Nanoparticles in Hair Care

5.4.1 Health concerns for carbon nanotubes were raised by in vitro and in vivo studies. Results of these studies showed that the size (longer tubes are more toxic), shape, length, and functionalization can affect the bio-distribution and elimination of the carbonnanotube, thereby contributing to higher or lower potential toxic responses. Pulmonary exposure is more likely the route of exposure, and so carbon nano-fibrous shape is important for the development of lung pathogenicity, inflammation, fibrosis and granuloma formations [35].

5.4.2 The US Food and Drug Administration has only approved minoxidil and finasteride as treatments for hair loss. According to one study, the encapsulation of minoxidil into solid lipid nanoparticles was found to have comparable skin penetration to commercial solutions without corrosivecharacteristics like causing dryness, irritation, burning, etc. Finasteride, a 5-reductase inhibitor that prevents the peripheral conversion of testosterone to dihydrotestosterone, has a number of undesirable side effects when taken orally. It has been suggested that the encapsulation of finasteride into topical liquid crystalline nanoparticles can bea possible alternative to oral administration so as to maintain high skin retention in the scalp, reduce frequency of doses, and decrease significant side effects such as mood disturbance [36].

6. Conclusion

The distinctive features of nanoparticles account for nanotechnology's significant influence in the cosmetics industry. Moreover, the potential seen in nanotechnology has revolutionized the industry. Many manufacturers have incorporated nanoparticles in the production of cosmetic products. The benefits of nanoparticles engineered into various cosmetic products have been noted in several publications and among those include deeper skin penetration, greater entrapment, better dispersibility, longer-lasting effects, enhanced UV protection, improved color and finish qualities, and protection of sensitive and volatile active compounds. Initial progress has been made on the use of nanotechnology for the delivery of cosmetic products such as moisturizers, sunscreens, and those belonging to lip care and hair care. However, there is still a need for further study and a much greater understanding of its safety, effectiveness, and toxicity before such innovation can be made widely available and accessible to the general public.

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