International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Utilizing Nanotechnology in Basic Skincare Regimen Cosmeceuticals : A Review

Frayne Bless J. Alaba[1] · Aira Faye C. Barote[1] · Alan Grant S. Calalas[1]· Ed-jay D. Cañete[1]· Will V. Castillo[1]· Hannah Mae U. Encendencia[1] · Hazel Anika L. Faco[1] · Rizelle Joy D. Gegare[1] · Edelweise H. Genelsa[1] · Cristine Ray P. Laluna[1] · Ma. Esperanza Mae L. Morong[1]· Wayne Rose L. Padayhag[1] · Zyarrah Zaida B. Pangolima[1] · Bin Salih S. Pantalan[1] · Aubrey May A. Villegas[1] · Fatima May R. Tesoro[1]

[1] **Pharmacy Department, San Pedro College, Davao City, Philippines**

DOI: https://doi.org/10.55248/gengpi.2022.3.5.16

A B S T R A C T

Nanotechnology has brought promising effects on cosmetics. Due to its minute dimension, skin barrier penetration has been a lot easier which results in enhanced delivery of chemicals. Integrating this technology in creams, serums, moisturizers and sunscreens has improved its anti-aging, firming, moisturizing and protective effects on the skin. However beneficial, drawbacks such as safety issues due to possible cellular uptake have posed a threat to human consumption. This review on the utilization of nanotechnology in skincare products specifically in creams, serums, moisturizers and sunscreens highlights the different nanoparticles used in skincare formulation as well as their positive and negative impacts, and efficacy analysis.

Keywords: Nanotech-based cosmeceuticals, skincare, basic skincare, nanotech, skincare regimen, cosmetics

Introduction

Industries such as cosmetics and pharmaceuticals provided a broad array of skin care products that would give treatments and care by cleansing, calming, restoration, strengthening, and protecting the skin from deterioration. Even before, these products are being used around the world for beautification. Commercialization and claims of these products are available in the market and are frequently predicated on an effect elicited by an activity that is given through a vehicle that uses a particular technology such as nanotechnology [1]. In the twenty-first (21st) century, nanotechnology, a potentially innovative approach in the world of cosmetics, is recognized as a promising technology [2].

Nanotechnology takes a distinct place among the technologies utilized to create attractive and efficient cosmeceuticals. Within the realm of cosmetics, tiny particles are considered to be efficiently absorbed into the skin for effective damage healing. Nanotechnology integration in skincare products could make creams more comfortable to be used and easy to spread, make scents linger longer, in sunscreen to effectively shield the skin from harmful UV rays, anti-aging cream to fight premature aging, and moisturizers to keep the skin hydrated [3].

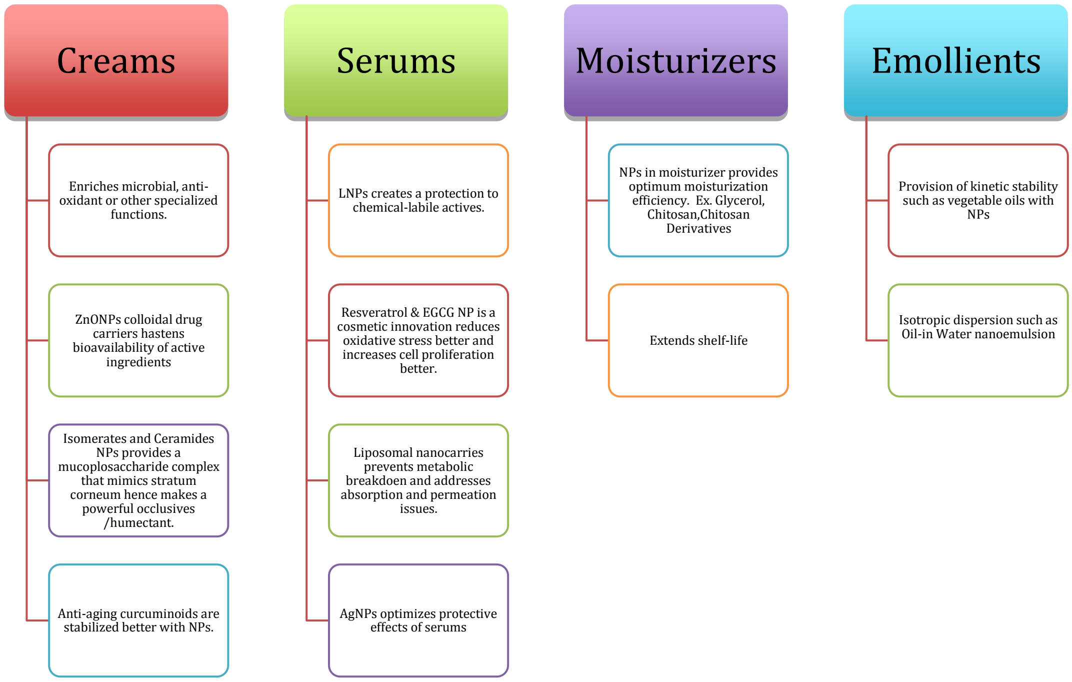
Basic skincare regimen is composed of three – cleansing, toning and moisturizing [4]. However some regimens like the Korean's, follow a 10-step skincare routine which starts with the application of foaming cleaner, followed by an exfoliant, then toner, serum, and essence [5]. In line with the aforementioned, this type of technology and ingredients used in preparation of these products would greatly affect its effectiveness; the use of nanotechnology has enhanced the function of cosmetics in a multitude of ways, whether functioning as a carrier or active ingredients [6].

Creams, serum, moisturizer and sunscreenare great products for anti-aging, anti wrinkles, anti-hyperpigmentation, anti-inflammatory and many more depending on its active ingredient [7]. Nanotechnology-based skincare products—including creams, serums, moisturizers, and sunscreens—have gained a lot of impressive benefits as it could penetrate the skin barrier due to its small size. However, although beneficial, the short and long-term toxicity of this technology is still unexplored [8]. Thus, there have been safety issues since the penetration of the chemicals could go deeper which could possibly lead to cellular uptake, hence resulting in cellular damage [9].

Methods

For this article review, a well-structured literature study is conducted to locate credible data or journal articles such as current publications of indexes and materials that primarily centers in studying skincare products that use nanotechnology including creams, serums, moisturizers and sunscreens. Following the collection of considerable evidence, significant data was analyzed for importance, validity, and appropriateness in accordance with the study, which will fill in the gaps in research. Before submitting the paper to any journal database, it is examined frequently to make necessary revisions.

Application of Nano-Technology



Creams

With a relatively fluid consistency, creams are homogenous, semi-solid, or viscous formulations designed for external application to certain mucous skin membranes for protective, therapeutic, or preventive reasons, particularly where an occlusive effect is not needed. Pharmaceutical creams are marketed to the general population that are intended to cleanse, beautify, moisturize, and protect the skin against bacterial and fungal diseases [10]. Nowadays, the majority of nanoparticles included in creams for specific functions such as cleansing creams, cold creams, foundation creams, vanishing creams, night creams, massage creams, and hand and body creams may be utilized for both lipophilic and hydrophilic drug delivery [11,12,13]. With this, this article discusses nanotechnology in creams based on their classification according to their functions.

Cold Cream

Cold cream is water-in-oil emulsion frequently made up of four major components: water, oil, an emulsifier, and a thickening agent, in nearly equal amounts. These formulations provide outstanding make-up and grease removal properties to form a nongreasy feel on skin [14].

Zinc Oxide (ZnO) Nanoparticles

Zinc Oxide (ZnO), frequently utilized in the formulation of creams, lotions, and as well as ointments, has potential in effectively providing antibacterial effects for skin disease treatment. Besides that, it also protects the skin from damage due to intensive exposure to sun and UV radiations. A cosmeceutical formulation enriched with ZnONps is known for its microbicidal, antioxidant, and moisturizing properties.

Biogenic ZnONps has the potential to be used in nanomedicine as promising biomaterials capable of significantly alleviating infection of the human skin and cellular destruction caused by oxidative stress. Incorporating colloidal ZnONps from biological sources into a nano cosmeceutical product and testing versus biologically and clinically significant pathogens found on the skin revealed significant antimicrobial and antioxidant properties. Further studies on cosmetic products utilizing ZnONps as carriers of colloidal drugs are encouraged for the increase of active ingredients bioavailability. Additionally, studies show the growing body of evidence demonstrating that nanotechnology improves and intensifies the function of personal care products used to treat various skin conditions [15].

Moisturizing cream

Moisturizers are the go-to relievers to alleviate dry skin, including those associated with dermatitis like eczema among others, through promotion in the repair of the barrier of the skin, establishing short-term artificial skin barriers for restoration of the integrity of the skin. They primarily intend to increase the mechanism of the skin's hydration and protect it from various influences that accelerate water evaporation, thereby reducing transepidermal water loss (TEWL). As the most widely used formulation, cream-based moisturizers are used as skin protectors, lubricants, softeners, drying agents, and other specific reasons.

Saccharide isomerates and Ceramide

Saccharide isomerate (SI), a purely natural carbohydrate complex and a product of sugar isomerization technology, is an artificial glycan that can form hyaluronic acid in the epidermis. Under high or low level humidity, hyaluronic acid functions to maintain the moisture in the stratum corneum by keeping it hydrated. Hence, it is an effective occlusive and humectant component in cream moisturizers. Ceramide, on the other hand, can be natural or synthetic. A man-made ceramides are generally incorporated in moisturizers to combat dry skin while endogenous ceramide is a hydrophilic molecule located in the horny layer of the skin, specifically in its extracellular matrix, that interacts with a structural matrix protein to provide the natural skin protective activity.

Generally, the formulation of synthetic ceramide in cream moisturizers is of solid lipid nanoparticle (SLN). Because it is composed of lipids, specifically, physiological lipids in the lipid matrix, SLN makes it less toxic [16]. Hence, moisturizing creams containing saccharide isomerate and ceramide have shown promising results to decrease transepidermal water loss (TEWL).

Hand and Body Protective Cream

Hand and Body Protective Cream, often known as barrier cream, is a topical preparation designed to preserve the structural integrity of the skin against chemical compounds, cleaning solutions, corrosive agents, and general dryness produced by regular handling and usage [17].

Silver nanoparticles

Silver nanoparticles (AgNPs), one of several metallic nanoparticles, are one of the most significant and intriguing nanomaterials employed in biological processes. It is crucial in nanotechnology and in nanoscience, and is notable in nanomedicine [18]. In a study conducted by Ahmed et al. [19], biosynthesised AgNPs using indian lilac were utilized via microwave irradiation. At 408 nanometers, a surface plasmon resonance band in the UV-visible spectroscopic range verified the breakdown of silver metal into AgNPs as well as its nanoparticles. In the making of bio Ag nanoparticles, reducing enzymes act as scaffolds, while terpenoids act as surfactants to stabilize the synthesized AgNPs. The former is taken from the aqueous extract filtrate of the *Azadirachta indica* that reacts with Ag ion from AgNO3.

Silver nanoparticles' therapeutic properties revealed that antimicrobial and anti-inflammatory properties are the primary attraction in the development of nano cosmeceutical products when compared to conventional hand and body cream. Silver nanoparticles (AgNPs) are undeniably an important and valuable addition to the cosmeceutical industry due to their beneficial therapeutic properties. As a result, AgNPs play an important role in the development of new and diverse cosmetic formulations that can prevent or treat common skin diseases, heal damaged skin, and maintain the overall health and quality of the skin over time. The physical and chemical properties of these nanoparticles, which are modified during their synthesis, influence their ability to exert beneficial effects.[20]

Anti-aging cream

Anti-aging creams are cosmeceutical products based on moisturizers used to reduce wrinkles, expression lines, blemishes, pigmentation changes, discolorations, and other environmental related skin conditions. Skin aging is divided into three categories: laxity, rhytids, and photoaging, which includes erythema, dyspigmentation, solar elastosis, keratoses, and poor texture [21].

Curcuminoids

Curcumin is a water-insoluble molecule that has a wide range of pharmacological effects. Antioxidant, antibacterial, antifungal, antitumor, and anti-inflammatory properties which are some examples [22]. Acne, alopecia, atopic dermatitis, face photoaging, oral lichen planus, pruritus, psoriasis, radiodermatitis, and vitiligo can all be treated with it [23]. There is a significant possibility for a skin-delivered curcumin product that might directly target damaged tissues in the treatment of skin diseases but on the other hand curcumin has a low passive skin penetration from simple lipid-based carriers due to its high lipophilicity [24]. Curcumin's limited bioavailability has been studied recently because of poor absorption, quick metabolism, and rapid systemic elimination. Utilizing curcumin in nanotechnology has the potential to alter the way we treat illnesses. Numerous ways for enhancing curcumin bioavailability, plasma levels, and cellular permeability processes have been revealed in recent studies. Liposomes, polymeric nanoparticles, micelles, nanogels, niosomes, cyclodextrins, dendrimers, silvers, and solid lipids are emerging as viable curcumin delivery systems. Its key challenges, such as low solubility, instability, poor bioavailability, and rapid metabolism, have been overcome by the use of the aforementioned nanoparticle in malignancies, wound healing, Alzheimer's disease, epilepsy, ischemic disorders, inflammatory illnesses, and so on [25].

Curcuminoids, a group of three phenolic chemicals, have lately attracted a lot of interest in the cosmetics industry for their antioxidant capabilities. They are susceptible to acid and alkali hydrolysis, as well as oxidation and UV degradation. However, there are little to no scientific trials to look at the effects of curcuminoids as a topical anti-aging cream. The majority of research employed only curcumin as the test substance, most probably due to a difficulty with topical preparation stability of curcuminoids. Over the past 10 years, solid lipid nanoparticles (SLN) have been successfully utilized to create topical formulations such as insect repellents, anti-aging treatments and other related products in the cosmetic industry. A study used SLN to overcome the stability barrier, making it the first to test curcuminoids effectiveness as a topical anti-aging treatment. The active component, curcuminoids, and its transport carrier, SLN, were thought to be responsible for the significant effect of curcuminoids loaded SLN cream on the outcome measures in this study. The antioxidant activity of curcuminoids decreased skin wrinkles and demonstrated skin whitening impact, whereas the occlusive property of SLN increased skin hydration, elasticity, and viscoelasticity. The active compounds were shown to be more stable thanks to SLN, which protected them from photo degradation and so extended their release from the system. There has never been a clinical experiment to look into the effects of curcuminoids as an anti-aging cream [26].

Serums

Serums are one of the most notable parts of the basic skincare regimen. This product was developed with the intent of being able to provide moisture on the skin, as well as become an aid to keeping the skin firm. Additionally, it helps reduce rhytids, being signs of aging, thus, it is recommended to be used after cleansing the face – may it be from a long day outside, a rest from heavy makeup, or even when staying at home. Being a cosmetic product, serums have been widely developed in ways that help in improving its initial purpose, including the utilization and application of nanotechnology.

Lipid-Based Nanoparticles (LNPs) in Serums

Lipid-based nanoparticles (LNPs), as known, are those that are made using a solid particle matrix, through the substitution of liquid lipid, or oil, for the liquid lipid oil in water emulsions, one being solid at body temperature. These can be seen in two (2) generations, namely: nanostructured lipid carriers (NLC) and the other, being solid lipid nanoparticles (SLN). NLC and SLN have a similar manufacturing process for actively dissolved by melting lipid phase upon which they are distributed in stabilizer solution or hot aqueous surfactant, having the same temperature with the former through high speed stirring [26]. After the emulsion droplets crystallizes post-cooling, it will then generate the lipid nanoparticles having a solid particle matrix.

Table 1. Examples of molecules encapsulated in formulations based on lipid nanoparticles for cosmetic use [26]

Examples of molecules encapsulated in formulations based on lipid nanoparticles for cosmetic use, since 2010 until 2017.

Cutaneous formulation	Type of lipid nanoparticles	Lipid(s)/Surfactant(s)	Drug or active ingredient	Outcome
Nanoemulgel	NLC	Precirol® ATO5, Argan oil/Tween® 80	Argan oil	Improved skin hydration
Nanoemulgel	SLN and NLC	Compritol® 888 ATO, Miglyol® 812/ Lutrol® F68	Octylmethoxycinnamate	Increased protection against UV radiation
Nanoemulgel	NLC	Compritol® 888 ATO, Miglyol® 812/ Lutrol® F68	Ethyl hexyltriazone, diethylamino hydroxybenzoyl hexyl benzoate, bemotrizinol, octylmethoxycinnamate, avobenzone	Increased protection against UV radiation, compared to nanoemulsions
Aqueous Dispersion	NLC	Cetyl palmitate, Miglyol® 812, Cetiol® OE/Tegocare® 450, Tween® 80, Span® 20	Coenzyme Q10	Improved skin permeation of the compound
Aqueous Dispersion	NLC	Orange wax, rice oil/Eumulgin® SG	Lycopene	Improved antioxidant effect
Aqueous Dispersion	SLN NLC	Palmitic acid/Tween® 80 Stearic acid, Glyceryl monostearate, Media chain triglyceride/Soya lecithin	Quercetin	Enhanced antioxidant and anti-inflammatory effect
Hydrogel	SLN	Precirol® ATO 5, Gelucire® 50/13/ Dicetyl phosphate	Retinyl palmitate	Improved anti-age effects
Nanoemulgel	NLC	Precirol® ATO 5, vitamin E/Tween® 80	Vitamin E	Improved skin hydration and biocompatibility
Gel-cream	SLN	Beeswax/Poloxamer 407, Tween® 80	–	Improved skin hydration

Argan oil, Lycopene and Quercetin were considered as natural based products while the rest were synthetic to improve the implementation of both lipid phases and avoid problems in the forming of the product [26]. However being similar, NLCs are known to have a greater advantage especially given its flexibility of having a higher active loading in comparison with SLNs, as well as a stiffer incorporation with the active into the particle matrix throughout shelf life. The surface configuration of lipid-based nanoparticles are said to have the ability of modulating the capacity to bind serum proteins, necessitating a swift response in the prediction of serum protein binding affinity to these LNPs [27]. This response will help in the reduction of resource use in its production, as well as the reduction in costs for the assessment of nanoparticle carriers.

Toxicology in the use of LNPs in Serums

Despite having advantages in the formulation of cosmetics like serums, their toxicological impact may be derived from their reaction on the skin barrier, relating to their solubility, dimensions, surface chemical-physical properties and degradation tendencies [28]. One of which also includes their assistance in higher skin permeability, making them bind with different tissues inside the body, which may be linked to various bodily risks.

One example involves the use of gold nanoparticles (AuNP), which can be synthesized using plant extract, making its extraction relatively safe and cost-effective. Upon undergoing tautomeric transformation resulting in a form of keto, the liberation of highly excited hydrogens can thereby result from metal ions undergoing breakdown to form nanoparticles of Au, from Au3+ to gold ion. In a study by Waluyo and Sutriyo [29], the utilization of gold particles derived from Sidaguri extracts being formulated in a serum, despite showing high anti-glycation activity, has also shown eye irritation tendencies.

Resveratrol

The use of resveratrol, which is a naturally occurring polyphenolic phytoalexin originating from plants involving grapes and berries, in various cosmetic innovations has already been denoted, as it has shown various health benefits, including its proven ability of penetrating the skin barrier, as well as anti-aging abilities. It has also been said to have antioxidant properties, helping the cell protection from damage of UV radiation and other free radicals, through minimizing NF-kB and AP-1 factors. It also aids in the delaying of the photoaging process of the skin. Commercial products containing resveratrol include Ganique resveratrol anti-aging serum and Caudalie resveratrol-lift instant firming serum [29].

Vitamin E

Another active ingredient utilized in serums due to their moisturizing and nourishing properties is laboratory-derived vitamin E, listed as *dl-alpha-tocopherol* and is synthesized from petroleum products. Commercially available products containing the ingredient include Breylee Vitamin C Serum with Vitamin E + retinol, and Beyond Beautiful brightening facial serum with Vitamins C & E, known for its antioxidative and photoprotective properties. Since vitamin E is highly lipophilic and highly unstable with poor skin penetration, its effectiveness is thereby limited, thus the utilization of carriers like SLNs and NLCs for its topical delivery due to their skin compatibility and enhanced penetration into the skin. The physical stability, being increased through having such a carrier also is related with the particles' collisions, decreasing its dilution but increasing its viscosity [30].

Epigallocatechin Gallate (EGCG)

Being a constituent known for its performance in skin protection, epigallocatechin gallate, also known as EGCG, is a natural polyphenol that is also known for its antioxidative and anti-inflammatory effects, isolated from dried green tea leaves. For skin moisture retention and protective activity from UV radiation, EGCG is known to increase the viability of cells, an implication of the reduction of cell damage from UV radiation. Apart from that, EGCG is also known to increase moisture power in keratinocytes, maintaining the firmness of skin barrier further. Most of all, serums also being known for the prevention of premature wrinkling, EGCG has shown not only for its ability to increase cell proliferation, but also as an anti-wrinkling agent. Commercially, it is an ingredient in cosmetic products such as Yadah Green Tea pure cleansing balm, and The Ordinary caffeine solution 5% + EGCG [31].

Liposomes

The utilization of liposomes as nanocarriers are known in cosmeceuticals that have vesicular forms containing a core of aqueous and a bilayer of hydrophobic lipid. It is used through the encapsulation of drugs to help it be released in a regulated manner thereby preventing metabolic breakdown. Its known advantages include its usage being applicable for both hydrophobic and hydrophilic chemicals, as well as its active moiety in encapsulation, biodegradability, nontoxic properties, and biocompatibility.

Some serums in the market, specifically C-Vit Liposomal Serum by Sesderma, are known to utilize this nanocarrier; the product is known for its hydration, heightened collagen synthesis and skin elasticity, firmness, and brightening properties [32].

Nanoemulsions

In serums and other cosmeceuticals, nanoemulsions are utilized due to its stability, both kinetically and thermodynamically. Nanoemulsions are known to have a lipophilic core making them appropriate for the delivery of lipophilic compounds; they also have translucency and transparency physical properties. Apart from the aforementioned, nanoemulsions are known to have low viscosity, large interfacial area, as well as a high solubilization capacity [10].

Nanoemulsions are seen in various forms such as water-in-oil (w/o), oil-in-water (o/w). Apart from this, they can also be found in the form of bicontinuous. Specifically, o/w nanoemulsions are critical in various water-based cosmeceuticals such as serums. Since serums are not only limited to the face, nanoemulsion-containing hair serums are also found in the market. Its compatibility in being formulated in various cosmetics is denoted from its ability to form micellar nanoparticles that are small yet with high surface areas, allowing a more effective bioactive component transport on the skin [2].

Silver Nanoparticles

Another nanoparticle utilized in cosmeceuticals involves silver nanoparticles. For its synthesis, the conventionally used physical and chemical methods are utilized; since they are too costly and in totality, unsafe, biological methods are commonly practiced, entailing to its high levels of output, lasting nature, and dispersibility [32]. Moreover, due to its inability to penetrate through the human skin; however, if the skin barrier does not embody its function well, it may have the ability of penetrating the skin at levels (0.2% to 2%) that do not show any form of toxicity [33]. This specific nanoparticle is also known to have protective effects, albeit not yet explored at an intense level. In the market, silver nanoparticles having possessed anti-aging, antibacterial, and anti-inflammatory properties, they are found in anti-wrinkle creams, face packs, deodorants, and most especially, face rejuvenating serums [34]. Attributing to its antibacterial property, it is mostly used in anti-acne products [35], such as Nano Silver Skin Cream found in the markets.

Moisturizers

A moisturizer that provides flexibility to the skin may help to prevent this dryness of the skin from occurring [36]. Its primary function is to keep the moisture level of the human sknl stable [37]. Furthermore, these can be further subdivided into three namely Humectants, Emollients, and Occlusives, which offers long-lasting benefits when incorporated with nanotechnology [38].

Moisturizers Nanotechnology

Due to the ongoing moisturization provided by the humectant layer, nanotechnology-based products—especially liposomes, nanoemulsions, and solid lipid nanoparticles—largely reduce excessive water loss through the skin while keeping the skin moist. Skin moisturizers based on nanotechnology have much greater moisturization efficiency and longer shelf lives than traditional formulations. Lancôme and Nano-Infinity Nanotech are two cosmetic firms that produce skin moisturizers that use nanotechnology as an ingredient.

A) Humectants

Humectants are a type of moisturizer utilized in cosmetology to substitute natural moisturizing factors (NMFs) that are naturally found in the keratin layer of the skin [39]. Because of their ability to stabilize water, these humectants are extensively employed in a variety of industries, including food, cosmetics, and other disciplines. Also, a humectant acts as a carrier for the delivery of vitamins, antioxidants, and anti-inflammatory medications to the skin [40] and promotes skin retention[38].

Hyaluronic acid is another popular hydrophilic humectant that can attach and bind large amounts of water, as well as the key ingredient responsible for moisture retention in the skin. However, since the molecule is approximately 3,000 nm in diameter with intercellular spaces being only 15-50 nm with hyaline membrane levels only ranging from 6-10 nm, this makes it impossible for conventional HA products to penetrate into the deep dermis [41].

One of the advantages of nanotech-based humectants is that they can be released in a controlled manner. In an article published in the journal of nanoscience and nanotechnology, halloysite nanotubes were investigated for its potential as a nanocontainer for glycerol wherein its release surpassed 20 hours, allowing for a long-lasting moisturizing effect of glycerol [39].

A.1) Glycerol

Glycerol, a humectant, is an excellent option on the cosmetic application of halloysite because it contributes to the homeostasis of our skin by regulating the balance of water in the intercellular matrix. Using natural halloysite nanotubes, cosmetic nanocontainers for delaying the release of glycerol were developed. In the beginning, cytotoxicity testing of the nanocontainer was carried out due to the fact that it is essential to describe its biocompatibility as a criterion for its safe use. The halloysite nanocontainer was tested for its capacity to maintain cosmetic components by filling it with glycerol in water Following the filling of the nanocontainer with glycerin, polyelectrolytes were utilized to cover the container layer by layer in order to further restrict the rate of glycerol escape from the container [39].

A.2) Chitosan

Two deoxy-b-d-glucopyranose sugars are linked together in a linear copolymer called chitosan (CT), a copolymer with linear characteristics, comprising of the sugars 2-amino-2-deoxy-beta-d-glucopyranose and 2-acetamido-2-deoxy-beta-d-glucopyranose joined together. Only a few fungus of the Mucoraceae family are capable of producing the polymer. The de-N-acetylated polysaccharide chitin, on the other hand, is a commercially available product. After cellulose, it is the following most abundant biopolymer. Besides that, it may be seen in cuticles of insects, shells of crabs, and cell walls of fungi. Because of its ability to absorb negative charges from the skin surface, it is a well-known cationic humectant in the formulation of topical products and other cosmetic products [40].

A.3) Chitosan Derivatives

2-hydroxypropyltrimethyl ammonium chloride chitosan (HACC) exhibits excellent hydrophilicity, biocompatibility, and moisture absorbency being an intricate compound with positive ions across many areas. Although it is better than chitosan in terms of having superior moisture absorption and retention characteristics, HACC is found to be insufficient humectant.

Whereas, carboxymethyl chitosan (CMCS) has been reported to be not only water soluble, but also have the distinctive characteristics such as low adverse effects, high bioactivity, high catalytic capacity, and excellent hydrophilic ability. These characteristics promote it as an appealing choice that is extensively used in the cosmetic and personal care industries. Although its skeletal structure is quite similar to that of HA, its hydrophilicity and ability to retain water received much interest [42].

B) Emollients

Emollients are cosmetic compounds that assist to retain the skin's soft, smooth, and flexible look. Additionally, it work by staying on the skin's surface for long periods of time, and naturally occurring animal fats and vegetable oils were among the first emollients used for cosmetic purposes throughout history. [42].

When an extremely small amount of a specific liquid spreads across another, the two differing fluids are either partly or completely immiscible with one another, an emulsion is formed. Each element (texture, consistency, ease of application, etc.) contributes to the emulsion's qualities, making it critical to understand both the specific properties of each ingredient as well as the potential interactions with other ingredients [42]. Regardless of these characteristics, emulsions are a dispersion of one immiscible liquid into another that is stabilized by the presence of a third chemical, the surfactant. Nanoemulsions class of emulsions, which are distinguished by their tiny particle size (50–500 nm) and their ability to disperse in aqueous solutions. Nanoemulsions are systems that are both thermodynamically unstable and kinetically stable [43, 44, 45].
A study stated that in contrast to traditional emollients, emulsified nanoparticles are more beneficial to use as they acquire various advantageous properties such as opacity or invisible appearance and non-greasy consistency. On the other hand, the fundamental drawbacks of traditional emollients are their inability to distribute components such as ceramides to the active site in sufficient quantities which are primarily applied to the skin externally. Nano-emulsions, SLNs, and liposomes are commonly used in moisturizer preparations due to their prolonged therapeutic properties [46]. Moreover, Dhar, S., Rammoorthy, R., Deb, S., & Parikh, D. (2019) affirmed that damaged skin barrier must be treated with emollients and creams to prevent further damage. Nanoparticle-containing barrier emollients are more effective against water loss than lipid-containing moisturizers, as they also reduce the risk of skin dryness and other skin problems [47]. In comparison to the conventional formulations, nanoemulsions that utilize vegetable oils can improve the product performance which allows most of the active ingredients to reach the active site of action.

B.1) Nanoemulsion And Emollient Activity

B.1.1) Passiflora Edulis

Saturated and polyunsaturated fatty acids, as well as essential fatty acids, have previously been identified in the oil derived from the seeds of P. edulis var. Edulis are emollients with antioxidant and antibacterial activities in the cosmetic industry. Despite this, there have been no reports of the seed oil of Passiflora edulis var. edulis was once utilized in cosmetics, whereas the seed oil of Passiflora edulis var. Flavicarpa (also known as Passiflora edulis) is a well-known cosmetic ingredient that is classed as an emollient [45].

B.1.2) Vegetable Oils

Vegetable oils have been successfully used in cosmetics for many years due to their softening and smoothing properties, which are classified as emollients by scientists. It softens the SC and decreases skin irritation while also having anti-inflammatory qualities. It minimizes water loss by generating a protective layer on the epidermis. A shortage in fatty acids may cause extreme dryness of the skin, which can lead to a variety of health and medical problems. In this way, the usage of lipids as cosmetic components demonstrates the relevance of lipids in skin and hair care products [48].

B.1.3) Oil-In-Water Nanoemulsion

Nanoemulsions are attractive to the cosmetic, pharmaceutical, food, and other industries because of their low surfactant content, higher stability against coalescence, low viscosity, pleasing appearance, formulation versatility, and low cost. Nanoemulsions are particularly desirable as cosmetic treatments because of their small droplet size, which allows for more direct contact with the skin's stratum corneum (SC), hence boosting the quantity of active components delivered to the desired action site. Nanoemulsions may also transport active substances into the skin, enhancing skin layer penetration and, as a result, effectiveness [45].

C) Occlusives

Water cannot penetrate an oily substance on the skin's surface, allowing water to move from the lower viable epidermal and dermal layers to the top viable epidermal and dermal layers, replenishing the SC moisture [49]. Drug penetration into human skin has been found to be heavily influenced by skin moisture, which can be altered by occlusive substances. After topical application, SLN or NLC forms a film on the skin's surface that acts as an occlusive barrier, reducing water evaporation and preventing skin aging [50].

Occlusives that are often found in cosmetic products include petroleum-based products like petroleum and mineral oil, as well as paraffin and paraffin wax. The ability of lipid nanoparticles as cosmeceuticals to improve skin occlusion, as opposed to other cosmetic components, is what sets them apart from other cosmetic ingredients. The occlusion is responsible for the reduction in transepidermal water loss (TEWL), as well as for the smoothing effect on wrinkles that it has on them when they are closed up [51].

C.1) Semi-Solid Lipid Nanoparticle (SLN)

Semi-solid formulations containing SLN have considerably enhanced skin hydration in vitro and in vivo investigations compared to traditional O/W cream formulations. The main advantage of nano cosmeceuticals over conventional cosmetics is that they have particle sizes in the nano range. Semi-solid NLCs prepared with argan oil, although the particle size decreased with the increase in argan oil concentration, the occlusive effect of SemiNLC-1; SemiNLC-2 and SemiNLC-3 also decreased in all time intervals [49].

C.2) Carbogels

When particles are sticky, adhesion rises with particle size. This notion applies to all particle carriers, including liposomes, NLC, and SLN, which all generate a coating when applied topically. The occlusion factor was lowered by increasing the oil content in NLC dispersions. However, NLC 30 was selected to encapsulate a pophia medicine. NUC has a higher drug loading capacity than SLN while having a lower occlusive activity [50].

C.3) Cream Occlusion Tests

The study conducted by Hamishehkar, et al. explored the occlusion effects of lipid particles in different sizes *in vitro, ex vivo, and in vivo* to compare the occlusive properties between Solid lipid nanoparticles (SLNs) and solid lipid microparticles. In vivo studies showed that the SLN formulation is superior to Vaseline as a positive reference material. This may be because SLNs enter skin pores and clog them, preventing SC water evaporation [51].

Sunscreens

Sunscreen is a product that protects the skin from the harmful effects of ultraviolet (UV) radiation from the sun [52]. Following the discovery of the harmful effects of UV rays, sunscreen preparations became a must-have in regular skin care procedures. The efficacy of sunscreen, as evaluated by the sun protection factor, determines its capacity to protect the skin from ultraviolet-induced burning (SPF). Recent advancements in nanoparticle technologies for enhanced drug delivery show considerable promise for the administration of active ingredients. Solid Lipid Nanoparticles (SLNs) have so many advantages in terms of drug delivery that they have become an alternative to new delivery approaches. SLNs can be used for the improvement of ingredients' physical stability, suitability of incorporating lipophilic and hydrophilic drugs, more convenient to use in manufacturing processes, and it has lower costs compared to liposomes. They benefited the skin because they stay longer due to their smaller particle size and consequently inhibit water loss making skin more hydrated. When compared to other cosmetic products, sunscreen containing SLNs showed synergistic effects and better UV protection [53].

Titanium Dioxide and Zinc Oxide

UVA protection factor should be at least one-third of the overall sun protection factor, according to the US Food and Drug Administration [52]. With the underlying potential adverse effects of organic UV filters on human and environmental health, directives on sunscreen UV filters continue to progress as the US Food and Drug After recent research revealed their systemic absorption in the human body, the administration requested additional safety evaluations of typical organic filters. Titanium dioxide (TiO2) and zinc oxide (ZnO) are mineral UV filters that offer a replacement for organic UV filters [45]. The combination of these particles ensures broad-band UV protection since TiO2 is more effective in UVB and ZnO is more effective in UVA [52].

To overcome the cosmetic problem of opaque sunscreens, microsized TiO2 and ZnO are progressively being replaced with TiO2 and ZnO nanoparticles (NPs). The unwanted opaqueness is removed when TiO2 and ZnO NPs are used, although the required balance of UVA and UVB protection might be changed. This scenario could be improved by combining micro- and nanosized ZnO dispersions with nanosized TiO2 particles [52].

When considering the use of TiO2 and ZnO NPs in sunscreens, the physicochemical properties of the TiO2 and ZnO pigments must be considered. When particles get smaller than 100 nm, they develop new optical properties thus having the transparent appearance [52]. Whereas more significant and microsized particles scatter more light and form an unwanted white haze on the skin. It was also found out that a nanopowder of ZnO distributed in glycerin absorbs more UV light than a micro powder of ZnO dispersed in glycerin of the same mass [54].

TiO2 and ZnO nanoparticles retain their very effective UV light-absorbing capacity as well as absorb and scatter visible light. They are also more stable than conventional UV filters, requiring less reapplication, and are low irritant and allergy materials. TiO2 and ZnO respond differently when made into nanoparticles, which are typically 25 to 50 nanometres broad. Depending on the SPF range, the connection between SPF and application thickness vary. This is thought to be related to the slow plateau effect of UV absorbers, which are abundant in high SPF sunscreens [55].

Fucoxanthin

Antioxidant component Fucoxanthin, a bioactive compound and also a natural carotenoid actively found in various organisms (e.g. seaweeds—tangle and brown algae) is beneficial to one's health, especially for detoxification and anti-aging. This compound has been used in UV-B-induced cell damage, making it a functional component in SLNs and nanostructured lipid carriers (NLCs) being known as dispersion systems (especially SLN) with high drug loading capacities and reduction of toxic effects; NLC is also outstanding in the storage of bioactive compounds attributed from its high loading capacity and lower water content for particle suspension. As a result, evaluating the scale-up feasibility of sunscreen production, as well as improving bioactive bioavailability and stability employing lipid NP, is important as both a requirement and a booster for the whole product [56].

It is strongly corroborated by numerous analyses of samples supplied in the materials and methods part of the journal article that SLNs and NLCs have shown not only an increase in skin water content but also their UV-blocking potential. In terms of fucoxanthin-loaded samples, they have exhibited enhancing benefits as sunscreens, as well as their protective activity and long-term stability, which can aid in the application procedure for sunscreen manufacture [56].

Formulation

Organic filters are popular because of their commercial value as the majority of them absorb UVB well. The most often used organic UV filter which is octyl methoxycinnamate protects the skin from UVB and short UVA portions. The best UV filter is the inorganic component TiO2 as it does not cause allergic reactions; it has excellent stability and is not degraded by UV light. It works by chemical absorption or blockage of UVR, and reflection of the radiation. So with the organic and inorganic components together, a more effective sun protection factor will be developed. And to better the quality of the products, it is integrated into nanoparticles through the use of High Shear Homogenization. Integration of the organic and inorganic UV filters into SLN matrix enhanced the UV-absorption capacity of the sunscreen. SLNs were also proven to be great vehicles in sunscreens.

Cinnamates-titanium dioxide-zinc oxide micro-fine combination produced synergistic effect for a broad and better UV protection. Together with the use of lipid matrices, the UV filters can provide more protection capacity as there is increased viscosity and spreadability of the formulation enabling a better fixation for the skin [52].

Tests were done to evaluate the effect of sunscreen based on SLN. Parameters tested include spreadability and viscosity determination, particle size analysis, UV protection test, and rheological behavior of the formulation. Rheological study results indicated that the product follows pseudoplastic flow and possessed thixotropy, a necessary characteristic in cosmetic preparations for an easier spread which also coincided with the spreadability test where results showed increased mean zone diameter of the formulation. Viscosity test was tested using a cone and plate rheometer at 25 degrees Celsius with spindle 52. UV protection test on the other hand used in-vitro SPF test to calculate its protecting ability. Records displayed a direct relationship between SPF value and viscosity. Formulation with higher viscosity always have greater SPF values and out of all the formulations compared, the formulation of nanosuspensions with inorganic pigment 6% TiO2 and 6% ZnO2 distributed in decyl oleate and carnauba wax demonstrated higher viscosity and higher SPF value compared to others [52].

Flash Nanoprecipitation (FNP) can encapsulate both organic and inorganic UV filters, allowing for broad-spectrum UV protection. By adjusting the concentrations of core components and the protective block copolymer, the size of NPs may be easily controlled from 53 nm to 350 nm. Organic (A Plus or T 150) and inorganic (TiO2 or ZnO) NP formulations both yield stable NPs. The capacity to combine inorganic NPs and adjust the size of organic NPs allows for improved UV absorption and scattering. The combination of TiO2, A Plus, and T 150 demonstrated the ability to create "nanoparticle cocktails" that could be used to tune UV attenuation across UVA, UVB, and UVC wavelengths. The particle size stability and UV absorption of the composite nanoparticles was outstanding throughout time [57].

Safety

Larger particles of TiO2 and ZnO reflect UV radiation, but in their nanoparticle form they may absorb UV radiation that releases reactive oxygen species (ROS). These reactive oxygen species, commonly known as free radicals, are involved in photocarcinogenesis and skin aging. One probable explanation is because nanoscale particles are too small to scatter or reflect visible light, thus they become translucent, absorbing UV energy [58].

NP are catalysts in the production of ROS, thus making it harmful if they are able to penetrate in the subcutaneous layer of our skin. Although previous studies have shown that TiO2 and ZnO NP of sunscreen do not penetrate beyond the SC, there have also been multiple studies that say otherwise. Zinc nanoparticles were able to permeate the SC in one investigation utilizing a stable radioisotope zinc mixed into sunscreens that were applied to the backs of healthy male participants. In another study, mice and pigs were used. Results showed that TiO2 NP can penetrate the SC and enter deeper layers of the epidermis of both animals, thus causing pathological changes to the heart, spleen, liver and skin. There are also studies on scenarios where a person who is at the beach with altered skin barrier functions due to eczema may adversely induce further barrier damage by sunburn when swimming, dehydration, abrading skin in the sand may greatly enhance the movement of TiO2 and ZnO NP into the skin [58].

Toxicities of NP penetration are cytotoxicity, including DNA damage via ROS generation. TiO NP allows surviving tumor cells to be transformed into more aggressive fibrosarcoma cells. It also damages the DNA at every nucleotide. NP may also accelerate lipid oxidative processes causing enhanced disruption of cellular membranes. ROS formation due to NP penetration also causes premature skin aging and worsening of pre-existing cutaneous pathology. On the brightside, NP particles may form much larger aggregates and agglomerates reducing their photocatalytic effect, thus fewer NP available for skin penetration. But the use of surfactants, dispersants may prevent this agglomeration thus enhancing the effects of individual NP penetration. It should also take into account the numerous ingredients in sunscreen such as oleic acid, ethanol, octyl palmitate, castor oil, and many more that have been seen to act as penetration enhancers for NP across the SC [58].

Sunscreen nanoparticles (NPs) cause (photo)cytotoxicity and genotoxicity, and have been found occasionally in viable skin layers, particularly when combined with ZnO. Although silica-based coatings are the most effective, coating the particles cannot totally avoid photocatalytic effects which are strongest for anatase TiO2. The safety and effectiveness of NP sunscreens are influenced by the physicochemical properties of NPs, coatings, formulations, and skin, as well as their interactions with UV radiation and mutual interactions. Nanoparticles or nanostructures with all three exterior dimensions at the nanoscale may also be more bio reactive than traditional bulk materials because the surface area to volume ratio of particles increases as particle diameter lowers. When developing new sunscreens, caution should be exercised, and research into sunscreen nanoparticle stabilization, penetration, chronic exposures, and lowering free-radical formation should be prioritized [52].

Detecting and characterizing metal oxides NPs

Four distinct ways for analyzing unmodified sunscreens when they were applied on COM 6 were studied. Nanoparticles were detected in unmodified commercial sunscreen using VPSEM, AFM, LSCM, and XRD. As applied to COM 6, Figure 1 presents results from each of the four methodologies used to examine unmodified sunscreens. The formulation comprised particles of 100 nm or smaller, according to all of the methodologies. A complex sunscreen base was also present in Com 6, with micron-sized particles scattered throughout the sample. Analysis of the VPSEM image could possibly discount these features as a rising from the VPSEM analysis environment, AFM analysis identified them as arising from the sunscreen emulsion. XRD, although not an imaging technique, is able to provide information about the primary particle size of the metal oxides but not how those particles interact with each other [59].

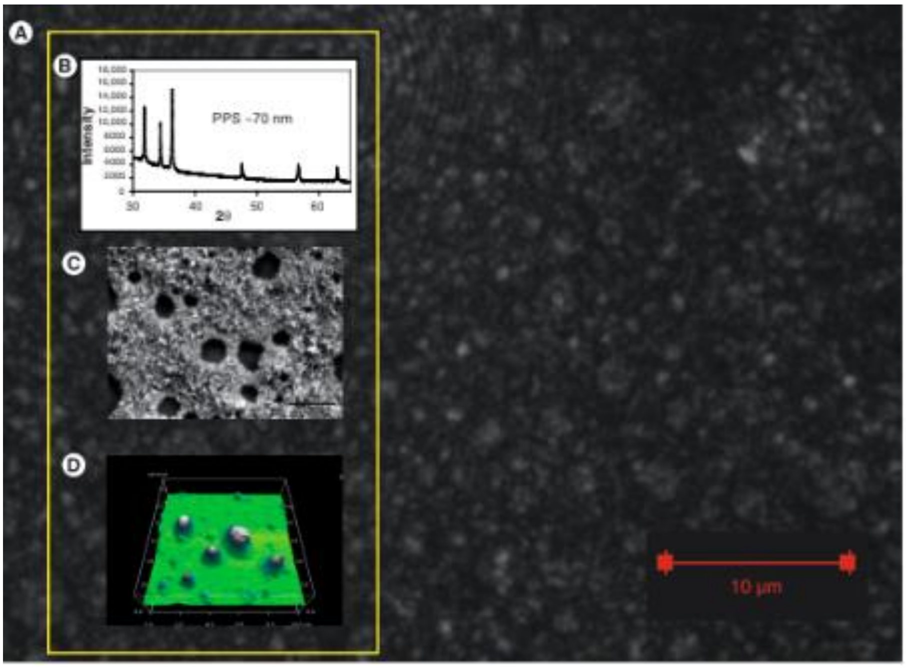


Figure 1. Comparison among (4) viable methods for commercial 6 (COM 6) at approximately similar scales for the imaging techniques. (A) Laser-scanning confocal microscopy, (B) X-ray diffraction (20 vs intensity, PPS ~70nm), (C) scanning-electron microscopy and (D) atomic-force microscopy (phase). 3D projection constructed through IGOR-PRO software on a previously flattened 2D image. PPS: Primary particle size. Retrieved from https://pubmed.ncbi.nlm.nih.gov/19193182/ [59]

While there are a range of analytical techniques for identifying and/or characterizing simple nanomaterial formulations, commercial products are complex materials. The unaltered end product should be analyzed to appropriately establish the nanoparticle state, interaction with the substance, and eventual consumer exposure. The automation of scanning electron microscopy (SEM) and atomic force microscopy (AFM) has been improved recently (AFM). Depending on the item under examination, the choice of appropriate analytical procedures will be increased or limited. A dry coating, for example, might be examined in full vacuum, allowing transmission electron microscopy to be used (TEM). Many of the scattering possibilities will be opened up with aqueous-based dispersion techniques [59].

Four analytical methods were demonstrated to be effective for identifying and characterizing metal oxide nanoparticles in unmodified commercial sunscreens. The use of VPSEM, AFM, LSCM, and XRD revealed that several of the commercial formulations contained unique nanoparticles, either as stable primary particles or aggregates. Furthermore, the approaches could describe the sunscreens in terms of particle dispersion and composition. Because of the intricacy of the sunscreen matrix and the requirement for unmodified analysis, the methods provided in this evaluation may be utilized as a basis for establishing a strategy to select analytical procedures for additional nanomedicine-related goods [59].

Discussions

Creams

Cold Cream: Zinc Oxide Nanoparticles

In the study of Sonia et al. [15], the formulation's antibacterial and antifungal activity was visually compared to commercial antibacterial and antifungal creams. The formulation was also stable, thanks to the extremely stable ZnONps, which kept its moisturizing properties for ninety days without causing skin irritations. The formulation outperformed a commercial antifungal cream by a factor of two against Candida species, a clinical skin infection. The commercial cream was resistant to the clinical isolate tested, whereas the designed ZnONps cold cream was vulnerable at a concentration of 2%. The cream base used as a negative control exhibited no activity. This demonstrates that cold creams containing antioxidant-rich nanoparticles can significantly alleviate skin infections and oxidative stress-induced cellular damage [15].

Moisturizing cream: Saccharide isomerates and Ceramide

The TEWL values imply that saccharide isomerate is effective in reducing TEWL in patients with eczema after 2 weeks of treatment. Such a finding is proved by the fact that the decrease in TEWL values among the SI group is higher compared to the control group (non-SI). The authors suggest that in comparison to conventional moisturizers, saccharide isomerate can significantly improve and maintain skin hydration [16].

Additionally, the TEWL values imply that ceramide SLN is effective in reducing TEWL in patients with eczema after 2 weeks of treatment. Such a finding is proved by the fact that the decrease in TEWL values among the ceramide (S) group is higher compared to the control (non-S) group. The study suggests that ceramides decrease both TEWL and the severity of eczema as well as increase the amount of natural ceramide in the skin. After the use of the moisturizing cream having both SI and ceramide, there has been a significant decrease in the TEWL values of eczema patients (Table 2) [16].

Table 4. TEWL Value of combination SI and S in eczema sufferers.

Treat ment	Groups	TEWLValue ($gr/m^2/hour$) Mean	p value
Before	SI S	-0,84083	0,092
After	SI S	-1,00167	0,032

Table 2. TEWL Value of combination SI and S in eczema sufferers [16]

Hand and Body Protective Cream:Silver nanoparticles

Ahmed et al. [19] investigated the antibacterial efficacy of smart handwash against Staphylococcus aureus, a bacterial pathogen, and Candida albicans, a fungal pathogen. The newly developed smartgel hand wash (NH5) had a substantially higher order of zone of inhibition than the control (NaCl) and marketed germ prevention detergent-based solution. The enhanced smart-gel hand wash (NH5antibacterial)'s activity is most likely due to changes in membrane permeability and bacterial enzyme breakdown. The consistency of smart-gel hand wash may be modified while washing hands, making it more antibacterial. As a consequence, it was discovered that the smart-gel hand wash is beneficial due to its compact size. It is biocompatible, effective, and inexpensive for sanitizing hands for daily duties. This suggests that gel-based hand wash containing a high concentration of AgNPs might be a viable substitute for standard hand wash.

Anti-aging cream: Curcuminoids

Plianbangchang et al. [26] investigated the effects of a cream containing curcuminoids SLN on skin wrinkles, hydration, color, elasticity, and viscoelasticity. The antioxidant activity of curcuminoids decreased skin wrinkles and whitening effects, but SLN's occlusive action increased skin hydration, elasticity, and viscoelasticity. Studies state there is no significant variation in the participants' skin pH, both between the sides of the application and in comparison to the baseline. Furthermore, the average skin pH was confirmed to be optimal during the study. A dermatologist and self-reports from participants were also utilized to determine skin discomfort.

Serums

Nanostructured Lipid Carriers

Occlusion levels on the skin attributed to film formation

Ahmed et al. (2019) reveals that nanoparticle occlusion—or its ability to form film on the skin resulting in an occlusion effect—is seen to be substantially higher than microparticle-based lipid suspensions having similar lipid fragments. On the other hand, the incorporation of LPNs is said to amplify the occlusion factor [19].

Enhanced bioavailability on the skin of active ingredients

Through a tape stripping test, it is justified that SLN suspension has shown better results, however, with emphasis that cosmetic products especially for the skin should not have any systemic effects. This then results in the suggestion that there should be a desired range of penetration for cosmetics on skin [19].

Resveratrol, Vitamin E, and EGCG in Nanoparticles

Since nanoparticles provide a large concentration of these active components in aqueous-based cosmetics, there is an increased benefit in its usage. The source yields that cholesterol or lipid ratio and the concentration of surfactants are attributed to the size and stability of nanoparticles. Cosmetic products with these active ingredients have also shown high homogeneity and stability. Compared to the control, the lipid nanoparticle formulation significantly protected the active against UV radiation over the first 4–6 hours of UV exposure. At 4 and 6 hours, the phospholipon-based formulation retained 92 and 83 % resveratrol, respectively, but the free resveratrol solution retained only about 28 percent resveratrol [51].

Following that, the same study shows the UV-induced degradation profile of the active ingredients, wherein the concentration of two LPN formulations containing vitamin E. In this, the VE concentrations are retained in the formulation 5—88%, formulation 6—82%, and control—62% [51]. In continuation, the degradation profiles of both formulations and control are seen, wherein VE LPN 5, VE LPN 6, and VE solution in ethyl alcohol (control) are shown to have only little variations [52]. Finally, the same study shows that resveratrol LPNs loaded have a significant linear improvement in the stratum corneum penetration of cosmeceuticals after 24 hours, as compared to its initial penetration [51].

Nanoparticles in Anti-Aging Formulations

Nanoparticles, due to being widely used in anti-aging products attributed to their anti-aging properties, antioxidant skin delivery is deemed possible. As most of its components cannot pass through the skin, retinoids administered topically, as well as skin rejuvenation connected to its antioxidative properties, can be accomplished using nanotechnology. Anti-ageing is the fourth most popular skin care claim, according to Mintel. In 2010, Europe had the largest anti-aging skin care market. Consumers want to look good for their age for as long as possible, as evidenced by the rising demand for anti-aging products, as shown in Table 3 [52].

Table 3. Active Ingredients in Anti-Aging Nanoparticle-Based Products [52]

Active ingredients/delivery system	Trade name	Manufacturer	Use
Ascorbyl palmitate, Tocopherol , retinol/ liposomes	Rovisome ACE Plus	Rovi Cosmetics International GmbH	Anti-ageing, wrinkle reduction.
Vitamin E/Nanotopes	Tinoderm E	Ciba Specialty Chemicals	Anti-inflammatory, anti-ageing.
Coenzyme Q10,Niacinamide/Liposomes	Ageless Facelift cream	I-Wen Naturals	Anti-ageing, anti-oxidative, wrinkle reduction.
Micro-encapsulated VitaminC (5%)	Ultimate Anti-Ageing Cream	Provin Cosmeceuticals	Anti-ageing, wrinkle reduction.
CoenzymeQ10,Vitamin E acetate/Nanoemulsion	Nano-Lipobelle H-EQ10 cream	Mibelle Biochemistry,Switzerland	Anti-ageing, anti – inflammatory.
Pro-Retinol A/Nanoparticles	Revitalift	L'Oreal	Anti-wrinkle, anti-ageing.
CoenzymeQ10/Nanostructured lipid carriers	Cutanova Nano Repair Q10 Cream	Dr.Rimpler GmbH	Revitalising , anti-ageing
Black current seed oil/Nanostructured lipid carriers	Nanolipid Restore CLR	CLR Chemisches Laboratorium Dr.Kurt Richter GmbH	Revitalising,anti-ageing
Vitamins A.E,C/Nanoemulsion	Nano-Lipobelle H-AECL	Mibelle Biochemistry, Switzerland.	Anti-wrinkle, antiageing.
VitaminE,Panthenol/Nanocapsules	Lancôme Soleil Soft-Touch Anti-Wrinkle Sun Cream SPF 15	L'Oreal	Revitalising, anti-ageing.
Grape seed extract, Vitamin E,Green tea extract/ Fullerenes	Sircuit Addict Firming Antioxidant Serum	Sircuit Skin Cosmeceuticals Inc.	Revitalising, anti-ageing.

Gold Nanoparticle-Containing Serums

In the anti-glycation test, results provide relevant data on the minute difference in the glycation inhibition activity of the formula with 10% concentration of AuNP and formula with 20% AuNP showing significantly-better inhibition activity, which are significantly higher than the positive control [21].

The irritant test shows differences in the irritation score of the test solutions. For NaOH 0.9%, or the negative control, it has shown that it is a non-irritant, as well as the serum base, serum containing 10% AuNP, and serum with 20% AuNP. Only the positive control, which is NaOH 0.1N has shown signs of being a strong to severe irritant based on the irritant classification [21].

Moisturizers

A) Humectants

A.1) Glycerol

In comparison to the halloysite sample from New Zealand, the halloysite sample from the United States seems to be a superior container for the prolonged release of glycerol. Furthermore, the sample from the USA demonstrated that the majority of the glycerol had been loaded into the nanotubes since there was no first burst. The halloysite nanotube developed in the USA is cosmitecally relevant since the complete release duration of glycerol from its structure much exceeds 20 hours [31].

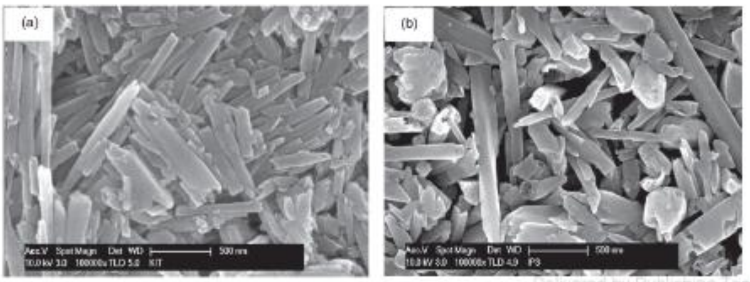


Figure 2. Scanning electron microscopy (SEM) photographs of halloysites from the United States and New Zealand, respectively [31].

This shows that the layer by layer nanoassembly has no obvious influence on the rate at which glycerol is released, as seen in Figure 2. It could possibly be due to glycerol's higher water solubility and reduced molecular weight, glycerol particles can possibly move into water due to the enormous concentration difference between them. Polymers with a larger molecular weight, such as chitosan or gelatin, may create a longer delay in the release of glycerol when layered together. Combining nanoparticles that narrow the lumen ends to further restrict the lumen ends will be a more effective way to minimize glycerol production [31].

A.2) Chitosan

A.2.1) Moisture absorption and retention

The significant partial pressure of saturated vapor detected at the time of the study led the particles to have a high absorption activity, resulting in the moisture's dynamic behavior observed for the nanoparticles, according to the findings. A "boost" in the moisture content was present when water sorption begins which is due to the extraordinarily high pressure difference between the nanoparticles and their surroundings at the start of the process. The moisture content of nanoparticles reached a plateau when equilibrium was reached with the relative humidity that is referred to as the optimum point of equilibrium. The hygroscopicity of the polymeric nanoparticles is shown to be a substantial component in their moisture absorption capacity. Chitosan contains both a strong hygroscopic nature and a high capacity to create hydrogen bonds with water which makes it an excellent gelling agent. Chitosan is exposed to the air for about 100 minutes. It absorbs 14 to 16 percent weight percent of water with 60 percent relative humidity at room temperature. This shows that presence of acacia or TPP has no effect on the freeze-dried nanoparticles' moisture absorption ability [31].

A.2.2) Skin Penetration Study

Human and pig skin have the same attachment, hair coat, epidermis and dermis thickness, presence of panniculus carnosus, and healing process. This approach produces an ionized nanosphere with a smooth surface that can depolarize negatively charged cell walls and can be utilized to distribute encapsulated medications or cosmetic functional components into the skin through the epidermis. The cell viability assays conducted on both CT NP's samples confirmed that they were non-toxic to human skin fibroblast cell lines. Internalization of the CT/TPP and CT/CA NPs into these cells is shown to be dominated by these NPs. Chitosan-acacia polymeric nanoparticles can be able to penetrate the dermis layer and transport active substances [31].

A.3) Chitosan Derivatives

The water absorption and moisture retention of chitosan, inulin, and its derivatives were compared to (Sodium Hyaluronate, HA). The results showed that all HACC derivatives, including those containing carboxymethyl polysaccharide anion and other anionic substances, had significantly better moisture uptake and retention. The result showed that HACCMI had the best moisture retention across the full range of relative humidity, whereas HACCBA had the best moisture retention across the entire range of relative humidity. Due to their excellent moisture absorption and retention properties, HACC derivatives may be employed as humectants in biomedicine, food, medicine, and cosmetics. [31].

B) Emollients

B.1) Nanoemulsion And Emollient Activity

B.1.1) Passiflora Edulis

The findings of oil extracted from the seeds of P. edulis var. edulis's seeds was tested on three subcontents to test its effectiveness based on Transepidermal water loss, skin moisturizing and skin viscoelasticity. Firstly, according to the study's findings, Tukey's multiple comparisons test after a two-way ANOVA revealed a significant difference between all of the treatments (p 0.0001). After using PEO and PEO nanoemulsion, transepidermal water loss (g/m2/h) was found to be reduced. The measures used to determine the amount of skin moisture, humectation, and viscoelasticity which revealed that all of the individuals who had been tested had increased skin moisture and viscoelasticity because formation of an occlusive film across the stratum corneum limits and prevents water loss from the skin thereby, improves stratum corneum hydration. For skin moisturizing findings, the study discovered that when the oil, vehicle, and nanoemulsion are applied, the water content increases when compared to the control. This is due to activities in the stratum corneum that aid in the skin's water retention and it shows that the moisture content of the PEO nanoemulsion is influenced by the activity of the oil contained in it. The nanoemulsion droplet size may also affect the results, as ideal droplet size allows skin penetration and improves skin moisture and hydration. The vehicle, PEO, and PEO nanoemulsions improved the stratum corneum's viscoelasticity, improving its biomechanical properties. Given the statistical differences between the vehicle, PEO, and PEO nanoemulsions, the improvement of skin viscoelasticity may be attributed to the stratum corneum's preservation and the composition of the oil produced from P. edulis var. edulis' seeds. [35].

B.1.2) Vegetable Oils

B.1.2.1) In-vivo Moisture Evaluation

The investigation included preliminary and expedited stability testing on the product. During the preliminary stability tests, the prepared samples were exposed to thermal stress which exposed that the products are unstable at high temperatures due to phase separation at 60℃. Next, electrical conductivity was tested. Due to a lack of linearity between the stability test and the instability procedure, it was impossible to determine the product's stability. However, its radius remained below 100 and are still considered as nanoemulsions. Next test conducted was to measure the polydispersion index (PDI). This test revealed that the formulations' PDI values remained at 0.2 which is indicative of their homogenic droplet population. Zeta potentials showed that the formulations were above 30 mV following the initial test, making them stable and ready for the expedited test procedure. Similar tests were conducted throughout the study. At temperatures of 25℃ and 40 ℃, there was a decrease in pH values that can be associated with degradation of some of the oil phase components, but this pH change did not imply instability as it still remained within the ideal pH values. It was also observed that at low temperatures, there is a better result for particle size tests. Zeta test values also did not show a decrease which implies that the formulation does not have a high flocculation tendency. Following sixty days, zeta potential remained nearly -40 mV, indicating strong physical stability. [35].

B.1.3) Nanolipids

Solid-lipid nanoparticles or SLN and nanostructured-lipid carriers or NLC are considered nanoparticles made of sturdy lipids or solid lipids. First-generation lipid nanoparticles or the SLN became developed first, followed by improved second-generation nanoparticles NLC at various periods. Many methodologies are utilized to describe their morphological and physicochemical properties. These include topographical features such as shape, size, surface morphology, and transmission electron microscopy. They are used in anti-aging products to defend against UV and IR radiation. The silver-nanolipid (sNLC) combination was already helpful in skincare for atopic dermatitis and psoriasis. SLNs have a lipid core, whereas NLCs have oils and solid lipids. Lipid nanoparticles are particularly well adapted for incorporating lipophilic compounds and peptides that are weakly water-soluble due to their lipidic composition. For this reason, lipid nanoparticles may be more successful than normal nanocarriers in carrying cutaneous products because they are soluble and durable [35].

C) Occlusives

C.1) Semi-Solid Lipid Nanoparticles (Sln)

C.1.1) Vegetable Oils

The sNLC compounds with mean size of particles within 208 and 429 nm and PDI levels only about 0.498. The typical size of the particles were 208-429 nm, and the PDI was below 0.498. Increasing aqueous lipids lowered sNLC particle size. When it comes to particle size, one of the most essential considerations is the structure of the lipid matrix. Because liquid lipids may be distributed more readily in water, it is predicted that increasing the quantity of vegetable oil used would cause particle size to decrease. The pH of among formulations removed the risk for skin reactions and discomforts in lengthy cosmetic and pharmacological treatments [39].

In several skin disorders, such as photoaging, hyperpigmentation, dryness, and wrinkles, nanotechnology-based cosmeceuticals are much superior than traditional cosmeceuticals. SLNs, the newest generation of lipid based nanocarriers, provide a very breakthrough technology for the skin care cosmeceutical world in terms of both efficacy and cost. The main advantage of nano cosmeceuticals over regular cosmetics is their nanoscale particle size. Vegetable oils are popular because they moisturize the skin. The study combined the advantages of lipid nanoparticles with vegetable oils to develop sNLCs that may be used in cosmeceutical applications. Thus, it is possible that the combination of the occlusion capabilities of lipid nanoparticles and vegetable oils will result in the observation of a synergistic impact on skin moisture[39].

C.1.2) Carbogels

C.1.2.1) NLC dispersions' in-vitro occlusive action

Because particulates are sticky, their adhesion increases with decreasing particle size. This concept applies to every particle transporter, particularly liposomes, NLC, and SLN, as all of these particle carriers create a coating when applied topically. Enhancing the oil's concentration in NLC dispersions reduced the occlusion factor, which was ascribed to greater imperfection of the matrix phase of lipids in the dispersion. Lipophilic medicine was encapsulated in NLC-30. Despite having a lesser occlusive action than SLN, NLC has a larger drug loading capacity due to the medication's improved solubility in oil.[39] .

C.1.1.2) NLC-based carbogel's in-vitro occlusive action

In a NLC-30 gel formulation, it is believed that the 4 percent produced a more effective occlusive effect than an 8 percent concentration. The higher oil content reduced the occlusion rate due to the enhanced lipid matrix imperfection. NLC-30 dispersion was chosen for drug loading because of its solubility in oil, while carbogel formulation was chosen for topical administration because of its solubility in oil. Adding humectants such Urea, Glycerin, and tinocare GL to the carbomer solution formed a carbomer gel. With regards to in-vitro occlusion, the pharmaceutical characteristics have been significantly enhanced[39].

C.1.3) Cream Occlusion Tests

C.1.3.1) In-vitro occlusion

The negative control revealed a significant amount of hydration loss - 63.7%. After 48 and 72 hours, the occlusion factor of F10 rose, indicating the difference between F10 and Vaseline was not statistically significant [39].

C.1.3.2) Ex-vivo occlusion

In ex-vivo occlusion studies, F9 (600 nm size) and F10 revealed no statistically significant difference (P>0.05) (1.8 m particle size)[39].

Ex-vivo and in-vitro research assessed SLNs' occlusive effectiveness. In-vitro and ex-vivo investigations might not have been suitable for assessing nanomaterials dosage formulations. The results are important for the cosmetics and pharmaceutical sectors since the 10% lipid formulation exceeded the gold standard, Vaseline. [39]].

Conclusion

The utilization of nanotechnology in skincare products has been remarkably increasing. Because it helps in the enhancement of penetration ability on the skin barrier, it has become a mode of delivery for various anti-aging, moisturizing, firming and protective effects of creams, serums, moisturizers and sunscreens. However, not all nanotechnology could penetrate the skin effectively such as silver nanoparticles. AgNPs are incapable of penetrating the skin barrier but it is still utilized in creams and serums for its anti-aging, antibacterial and anti-inflammatory activity. Although promising, this technology has not yet been intensively explored which poses a threat to human consumption. AuNPs could possibly cause eye irritation due to the reduction of gold ions. TiO2 and ZnO in nanoparticles as utilized in sunscreens could possibly cause skin aging and photocarcinogenesis due to the absorption of UV radiation. Thus, the novelty of nanotechnology as an integration in cosmetics should gain more intensive research on its safety for human use.

Compliance with ethical standards

Acknowledgments

The researchers would like to thank their professor, Mrs. Fatima May R. Tesoro, RPh, MSPharm for her heartwarming guidance throughout the making of this journal review. This will not be possible without the support from the institution, San Pedro College, helping the researchers become well-equipped in the making of this journal.

This journal article would not be possible without the help and brilliance of the whole 3rd year Section D BSPharmacy Batch

2021-2022, namely: Alaba, Pierce Adrianne A., Arcenal, Kelly James B., Buquia, Glenn Fiel D.,Cordero, Ramil Reese A.,Erum, Eddo L., Galvez, Dhinniell D., Guillermo, Maxyl Joshua T., Ng, Marc Ronan S., Sarabia, James Brian F., Avestruz, Pearl Raven Shannine D., Baldeo, Andrea Rei G. Buyser, Chlaire Dimple C., Dionaldo, Almarie T., Gregorio, Justine P., Guiam-An, Lyna D., Ladaga, Julienne Fae E., Larido, Gresha Sheine S., Maceren, Jeby Isabel G., Pedregosa, Denise Marfe S., Solorin, Meeka R., Sumampong, Maria Marissa Q., Taguba, Joanna Marie C., Torino, Julie Jill R., Vanzuela, Deserie Joy R., Yu, Lovely Dianne I.

They would also like to thank the presence of their families and friends for their undying love and support amidst the pressure felt to complete this journal review.

Finally, the researchers would like to thank the Almighty God, for bestowing upon them wisdom and resiliency for helping them thrive throughout the completion of this journal.

Disclosure of conflict of interest

No conflict of interest from the authors.

Reference

1. Surber C, Kottner J. Skin care products: What do they promise,what do they deliver [Internet]. Researchgate.net. 2016 [cited 2022 May 3]. Available from: https://www.researchgate.net/publication/299475540_Skin_Care_Products_What_do_they_promise_what_do_they_deliver
2. Aziz ZAA, Mohd-Nasir H, Ahmad A, Mohd Setapar SH, Peng WL, Chuo SC, et al. Role of nanotechnology for design and development of cosmeceutical: Application in makeup and skin care. Front Chem [Internet]. 2019 [cited 2022 May 3];7:739. Available from: https://www.frontiersin.org/articles/10.3389/fchem.2019.00739/full
3. Lohani A, Verma A, Joshi H, Yadav N, Karki N. Nanotechnology-based cosmeceuticals. ISRN Dermatol [Internet]. 2014 [cited 2022 May 3];2014:843687. Available from: https://www.hindawi.com/journals/isrn/2014/843687/?fbclid=IwAR1vzzyoyz78n1j5NsKMCuqn7itOCsFg0alli7alm4g8gmsQ_Nsc0_EQmmk
4. Molvar K. How to build a skin care routine. [cited 2022 May 6]; Available from: https://www.nytimes.com/guides/tmagazine/skincare-routine
5. Abad-Santos A. How the 10-step Korean skin care routine changed American skin care [Internet]. Vox. 2019 [cited 2022 May 6]. Available from: https://www.vox.com/2019/1/17/17450044/korean-skin-care-10-step-routine
6. Salvioni L, Morelli L, Ochoa E, Labra M, Fiandra L, Palugan L, et al. The emerging role of nanotechnology in skincare. Adv Colloid Interface Sci [Internet]. 2021;293(102437):102437. Available from: https://www.sciencedirect.com/science/article/pii/S0001868621000786
7. Into The Gloss. What is face serum? Why and how to use it [Internet]. Into The Gloss. 2016 [cited 2022 May 6]. Available from: https://intothegloss.com/2016/03/what-is-serum/
8. Raj S, Jose S, Sumod US, Sabitha M. Nanotechnology in cosmetics: Opportunities and challenges. J Pharm Bioallied Sci [Internet]. 2012 [cited 2022 May 6];4(3):186–93. Available from: http://dx.doi.org/10.4103/0975-7406.99016
9. Friedman A. Nanotechnology and dermatology - the role of nanotechnology in dermatology research [Internet]. AZoNano.com. 2010 [cited 2022 May 6]. Available from: https://www.azonano.com/article.aspx?ArticleID=2728
10. Chauhan L, Gupta S. Creams: a review on classification, preparation methods, evaluation and its applications. Journal of Drug Delivery and Therapeutics. 2020 Oct 15;10(5-s):281-9.
11. Kaul S, Gulati N, Verma D, Mukherjee S, Nagaich U. Role of nanotechnology in cosmeceuticals: a review of recent advances. Journal of pharmaceutics. 2018;2018.
12. Mu L, Sprando RL. Application of nanotechnology in cosmetics. Pharmaceutical research. 2010 Aug;27(8):1746-9.
13. Nohynek GJ, Lademann J, Ribaud C, Roberts MS. Grey goo on the skin? Nanotechnology, cosmetic and sunscreen safety. Critical reviews in toxicology. 2007 Jan 1;37(3):251-77.
14. Wivell SC, inventor; Chesebrough-Ponds Inc, assignee. Clear cold cream cosmetic compositions. United States patent US 5,525,344. 1996 Jun 11.
15. Sonia S, Ruckmani K, Sivakumar M. Antimicrobial and antioxidant potentials of biosynthesized colloidal zinc oxide nanoparticles for a fortified cold cream formulation: a potent nanocosmeceutical application. Materials Science and Engineering: C. 2017 Oct 1;79:581-9.
16. Hartini H, Vlorensia HA, Martinus AR, Ikhtiari R. The Effect of a Moisturizing Cream Containing Saccharide Isomerate and Ceramide on Reducing Transepidermal Water Loss in Eczema.
17. WorkplaceTesting. Protective Hand Cream [Internet]. WorkPlaceTesting.com. WorkplaceTesting; 2019 [cited 2022 May 12]. Available from: https://www.workplacetesting.com/definition/2315/protective-hand-cream
18. Zhang XF, Liu ZG, Shen W, Gurunathan S. Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. International journal of molecular sciences. 2016 Sep;17(9):1534.
19. Ahmed MM, Fatima F, Anwer MK, Alshahrani SM, Alalaiwe A, Katakam P. Biosynthesis, characterization and anti-microbial activity of silver nanoparticle based gel hand wash. Green Processing and Synthesis. 2019 Jan 1;8(1):577-83.
20. Ong WTJ, Nyam KL. Evaluation of silver nanoparticles in cosmeceutical and potential biosafety complications [Internet]. Saudi Journal of Biological Sciences. Elsevier; 2022 [cited 2022May12]. Available from: https://www.sciencedirect.com/science/article/pii/S1319562X22000353
21. Sharma B, Sharma A. Future prospect of nanotechnology in development of anti-ageing formulations. Int J Pharm Pharm Sci. 2012;4(3):57-66.
22. Noorafshan A, Ashkani-Esfahani S. A review of therapeutic effects of curcumin. Curr Pharm Des. 2013;19(11):2032–46. Available from: https://www.ingentaconnect.com/content/ben/cpd/2013/00000019/00000011/art00006;jsessionid=1ghl96qnf9p.x-ic-live-01
23. Salehi B, Stojanović-Radić Z, Matejić J, Sharifi-Rad M, Anil Kumar NV, Martins N, et al. The therapeutic potential of curcumin: a review of clinical trials. Eur J Med Chem. 2019;163:527–45. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0223523418310535?via%3Dihub
24. Chen, Y.; Wu, Q.; Zhang, Z.; Yuan, L.; Liu, X.; Zhou, L. Preparation of curcumin-loaded liposomes and evaluation of their skin permeation and pharmacodynamics. Molecules 2012, 17, 5972–5987. Available from: https://www.mdpi.com/1420-3049/17/5/5972
25. Ghalandarlaki N, Alizadeh AM, Ashkani-Esfahani S. Nanotechnology-applied curcumin for different diseases therapy. BioMed research international. 2014 Jun 5;2014.
26. Plianbangchang P, Tungpradit W, Tiyaboonchai W. Efficacy and safety of curcuminoids loaded solid lipid nanoparticles facial

cream as an anti-aging agent. Naresuan University Journal: Science and Technology (NUJST). 2013 Jul 31;15(2):73-81.

27. Garcês A, Amaral MH, Sousa Lobo JM, Silva AC. Formulations based on solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC) for cutaneous use: A review. Eur J Pharm Sci [Internet]. 2018;112:159–67. Available from: https://www.sciencedirect.com/science/article/pii/S0928098717306528
28. Sebastiani F, Yanez Arteta M, Lindfors L, Cárdenas M. Screening of the binding affinity of serum proteins to lipid nanoparticles in a cell free environment. J Colloid Interface Sci [Internet]. 2022;610:766–74. Available from: https://www.sciencedirect.com/science/article/pii/S0021979721020282
29. Waluyo DA, Sutriyo. Evaluation of anti-glycation effect and safety of serum anti-aging formulation containing gold nanoparticles (AuNP) using Sidaguri extract (Sida rhombifolia). Int j appl pharm [Internet]. 2022 [cited 2022 May 6];226–30. Available from: https://innovareacademics.in/journals/index.php/ijap/article/view/40417
30. Kim J, Oh J, Averilla JN, Kim HJ, Kim J-S, Kim J-S. Grape peel extract and resveratrol inhibit wrinkle formation in mice model through activation of Nrf2/HO-1 signaling pathway. J Food Sci [Internet]. 2019;84(6):1600–8. Available from: http://dx.doi.org/10.1111/1750-3841.14643
31. Saez V, Souza IDL, Mansur CRE. Lipid nanoparticles (SLN & NLC) for delivery of vitamin E: a comprehensive review. Int J Cosmet Sci [Internet]. 2018;40(2):103–16. Available from: http://dx.doi.org/10.1111/ics.12452
32. Zhang X-F, Liu Z-G, Shen W, Gurunathan S. Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. International Journal of Molecular Sciences [Internet]. 2016 Sep 13;17(9):1534. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5037809/
33. Kim E, Hwang K, Lee J, Han SY, Kim E-M, Park J, et al. Skin protective effect of epigallocatechin gallate. Int J Mol Sci [Internet]. 2018 [cited 2022 May 6];19(1). Available from: http://dx.doi.org/10.3390/ijms19010173
34. Kaul S, Gulati N, Verma D, Mukherjee S, Nagaich U. Role of nanotechnology in cosmeceuticals: A review of recent advances. J Pharm (Cairo) [Internet]. 2018 [cited 2022 May 6];2018:3420204. Available from: https://pubmed.ncbi.nlm.nih.gov/29785318/
35. Gajbhiye S &Sakharwade S. Silver Nanoparticles in Cosmetics [Internet]. Scirp.org. 2016 [cited 2022 May 6]. Available from: https://www.scirp.org/journal/paperinformation.aspx?paperid=65036
36. Nanocosmeceuticals for the management of ageing: Rigors and Vigors [Internet]. Researchgate.net. 2021 [cited 2022 May 6]. Available from: https://www.researchgate.net/publication/349677136_Nanocosmeceuticals_for_the_management_of_ageing_Rigors_and_Vigors
37. Lohani A, Verma A, Joshi H, Yadav N, Karki N. Nanotechnology-based cosmeceuticals. ISRN Dermatology. 2014;2014:1–14.
38. Ta Q, Ting J, Harwood S, Browning N, Simm A, Ross K, et al. Chitosan nanoparticles for enhancing drugs and cosmetic components penetration through the skin. European Journal of Pharmaceutical Sciences. 2021;160:105765.
39. Purnamawati S, Indrastuti N, Danarti R, Saefudin T. The role of moisturizers in addressing various kinds of dermatitis: A review. Clinical Medicine & Research. 2017;15(3-4):75–87.
40. Suh YJ, Kil DS, Chung KS, Abdullayev E, Lvov YM, Mongayt D. Natural nanocontainer for the controlled delivery of glycerol as a moisturizing agent. Journal of Nanoscience and Nanotechnology. 2011;11(1):661–5.
41. Dominguez, S, Mackert, G, Dobke, M. Nanotechnology to enhance transdermal delivery of hydrophilic humectants for improved skin care: a model for therapeutic applications. Nanostructures for Drug Delivery [Internet]. 2017 [cited 12 May 2022];919-939. Available from https://www.sciencedirect.com/topics/nursing-and-health-professions/humectant
42. Mi Y, Miao Q, Cui J, Tan W, Guo Z. Novel 2-hydroxypropyltrimethyl ammonium chitosan derivatives: Synthesis, characterization, moisture absorption and retention properties. Molecules. 2021;26(14):4238.
43. Mcclements, D.J. Nanoemulsions *versus* microemulsions: Terminology, differences and similarities. *Soft Matter* 2012, *8*, 1719–1729.
44. Kabri, T.-H.; Arab-Tehrany, E.; Belhaj, N.; Linder, M. Physico-chemical characterization of nano-emulsions in cosmetic matrix enriched on omega-3. *J. Nanobiotechnol*. 2011, *9*, 41.
45. Ribeiro R, Barreto S, Ostrosky E, Rocha-Filho P, Veríssimo L, Ferrari M. Production and characterization of Cosmetic Nanoemulsions containing opuntia ficus-indica (L.) mill extract as moisturizing agent. Molecules. 2015;20(2):2492–509.
46. Mittapally, S., & Afnan, A. A. (n.d.). A review on nanotechnology in cosmetics. Thepharmajournal.Com. Retrieved May 11, 2022, from https://www.thepharmajournal.com/archives/2019/vol8issue4/PartK/8-3-103-386.pdf
47. Dhar, S., Rammoorthy, R., Deb, S., & Parikh, D. (2019). Nanotechnology in pediatric dermatology. Indian Journal of Paediatric Dermatology, 20(4), 290. https://doi.org/10.4103/ijpd.ijpd_95_17
48. Ahmad A, Ahsan H. Lipid-based formulations in cosmeceuticals and biopharmaceuticals. Biomedical Dermatology. 2020;4(1).
49. Hamishehkar H, Same S, Adibkia K, et al. A comparative histological study on the skin occlusion performance of a cream made of solid lipid nanoparticles and Vaseline. *Res Pharm Sci*. 2015;10(5):378-387.
50. Khater D, Nsairat H, Odeh F, Saleh M, Jaber A, Alshaer W, et al. Design, preparation, and characterization of effective dermal and transdermal lipid nanoparticles: A Review. Cosmetics. 2021;8(2):39.
51. Enhanced occlusiveness of Nanostructured Lipid Carrier (nlc)-based Carbogel as a skin moisturizing vehicle. Journal of Pharmaceutical Investigation. 2010;40(6):373–8.
52. Smijs T, Pavel S. Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness. Nanotechnology, Science and Applications [Internet]. 2011 [cited 1 May 2022];:95. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3781714/
53. Nesseem D. Formulation of sunscreens with enhancement sun protection factor response based on solid lipid nanoparticles. International Journal of Cosmetic Science [Internet]. 2011 [cited 1 May 2022];33(1):70-79. Available from: https://pubmed.ncbi.nlm.nih.gov/20704600/
54. Guedens W, Reynders M, Van den Rul H, Elen K, Hardy A, Van Bael M. ZnO-Based Sunscreen: The Perfect Example To Introduce Nanoparticles in an Undergraduate or High School Chemistry Lab. Journal of Chemical Education [Internet]. 2013 [cited 1 May 2022];91(2):259-263. Available from: https://www.researchgate.net/publication/263036432_ZnO-Based_Sunscreen_The_Perfect_Example_To_Introduce_Nanoparticles_in_an_Undergraduate_or_High_School_Chemistry_Lab
55. Cave H. The nanotechnology in your sunscreen [Internet]. The Guardian. 2014 [cited 11 May 2022]. Available from: https://www.theguardian.com/science/small-world/2014/mar/13/nanotechnology-sunscreen-skin-cancer
56. Lee Y, Nam G. Sunscreen Boosting Effect by Solid Lipid Nanoparticles-Loaded Fucoxanthin Formulation. Cosmetics [Internet]. 2020 [cited 1 May 2022];7(1):14. Available from: https://www.mdpi.com/2079-9284/7/1/14
57. Shi L, Shan J, Ju Y, Aikens P, Prud'homme R. Nanoparticles as delivery vehicles for sunscreen agents. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2012;396:122-129.
58. Tran D, Salmon R. Potential photocarcinogenic effects of nanoparticle sunscreens. Australasian Journal of Dermatology [Internet]. 2010 [cited 1 May 2022];52(1):1-6. Available from: https://pubmed.ncbi.nlm.nih.gov/21332685/
59. Tyner K, Wokovich A, Doub W, Buhse L, Sung L, Watson S et al. Comparing methods for detecting and characterizing metal

oxide nanoparticles in unmodified commercial sunscreens. Nanomedicine [Internet]. 2009 [cited 1 May 2022];4(2):145-159. Available from: https://pubmed.ncbi.nlm.nih.gov/19193182/