

Review

Application of Nanotechnology Incorporated with Natural Ingredients in Natural Cosmetics

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Abstract: Technology and environmental innovations always have a growing emphasis and have affected various industries. Since the cosmetics industry is highly competitive and consumers always desire innovations in products, the cosmetics industry tends to launch new products to satisfy customer desires without exception. Recently, in the area of cosmeceuticals, the application of nanotechnology has been attempting to increase; however, it seems to be tackling certain disadvantages compared to traditional products. Cosmeceuticals based on nanotechnology offer the benefits of product differentiation, improved bioavailability, and prolonged effects of active ingredients. These are widely used as a regulated delivery medium for cosmeceuticals, such as shampoo, nail enamels, lotions, hair serums, and conditioners. Their wide application is attributed to their intrinsic properties, such as rapid penetration, stability, hydrating power, and texture. The ability of the nanoemulsion system to form small- and large-surface nanoparticles enable the bioactive components to be transported into the skin more effectively. Furthermore, natural cosmetics are a general term that refers to all preparations for external conditioning and beautifying of the body from ingredients produced by or found in nature. The purpose of this review is to understand the nature of natural cosmetics which incorporate nanotechnology for better encapsulation and a better drug delivery system. The importance of innovations in the cosmetic industry is also discussed.

Keywords: nanotechnology-based cosmeceutical; nanoemulsion; micellar nanoparticles; natural cosmetic



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1. Introduction

The skin is the main shield that protects the body from free radicals. There are numerous types of free radicals, which are generated by UV rays, dust, exposure to chemicals, and air pollution [1]. Free radicals are extremely harmful to human skin. The consequences that one might face from free radical exposure include damaging the elasticity of the skin and the production of collagen, which eventually leads to the formation of wrinkle lines, thus causing the skin to become less elastic. Moreover, it may interrupt the dissemination of melanocytes and melanin pigment, which may result in uneven pigmentation and skin cancer [2]. Rodan et al. stated that the most desired human feature is “flawless skin”, which is considered the fundamental human requirement for well-being and health, with a clear, radiant complexion that is even-toned [3]. Therefore, people of all

ages ambitiously look for ‘noble’ skincare products. The conception of youthful or perfect skin can be determined by the number of features of the dermis and epidermis, including the quality and density of extracellular matrices, variations of natural fluorescence in the skin, and the supply of cells to the connective tissues.

Consequently, skin physiology can be predicted from a variety of skin conditions, such as acne, abnormal pigmentation, and xerosis [4]. Hence, skin lesions evolve in response to nutritional deficiencies. Therefore, the amalgamation of cosmetic skincare and over-the-counter (OTC) products supplied through regimen is able to play a remarkable role in guiding consumers to rebuild beautiful and healthier skin again [5]. The existence of natural ingredients in skincare products improves skin conditions in these situations [6]. To gratify the large number of consumers by increasing the consumer demand for cosmetic products’ efficacy, it is indeed getting more difficult to distinguish between the active pharmaceutical ingredients and topical application of cosmetics [7].

2. Development of Cosmetics

Cosmetics can be described as products that enhance the attractiveness of the skin, intensifying, cleaning, and amplifying the appearance of the skin. As claimed, Egyptians are attributed with using cosmetics even in 4000 BC, and subsequent cosmetics were developed by Greeks, Chinese, Romans, Americans, and Japanese [8]. Furthermore, by the twenty-first century, cosmetics are used significantly, and innovative cosmetic formulations are established through the advancement of technology and the incorporation of the latest innovations [5,9]. In comparison, Asian cosmetics are among the best performing and are in high demand, which has been documented by the increase in the Asia-Pacific market value to more than US \$70 billion. In addition, according to data from Malaysia External Trade Development Corporation (MATRADE), Malaysia’s cosmetics market in 2019 was worth \$5 billion. The country’s export of Halal cosmetics products saw a 68% increase from 2012 to 2017, from \$433 million to \$725 million [10].

Numerous cosmetics now claim to protect against pollution and environmental harm. Is this conceivable? Yes, but some explanation is necessary. Air pollution is made up of small, highly reactive nanoparticles that are generated during combustion. Combustion happens when fuel is burned in a vehicle engine, coal is burned in power plants, waste is burned in an incinerator, or trees are burned in a forest fire. When these nanoparticles come into contact with the skin, they create reactive oxygen species, which cause skin damage by perforating elastin fibers and dermal collagen. The reactive oxygen species will not develop if the nanoparticles are not permitted to come into contact with the skin, and no harm will result. Most moisturizers and foundations will apply a thin coating of an oily occlusive material to the skin’s surface, usually using dimethicone, mineral oil, and shea butter. This thin layer from the cosmetic applied will hinder nanoparticles from air pollution from entering and having contact with the skin, hence preventing skin injury. As a result, it is possible to protect one’s skin against environmental harm with the proper cosmetic application.

3. Market Trend of Cosmetics

Since the twenty-first century, a number of multinational corporations have dominated the cosmetics industry [11]. There are six major categories in the global cosmetic industry, i.e., fragrances, hair care, makeup, oral care, skincare, and toiletries. Skincare products accounted for 41% of the global market in 2021 and was the largest product class. In 2020, negative annual growth was noticed, probably due to the spread of the COVID-19 pandemic; however, the industries recovered in 2021, as the rate grew by 8% [12]. According to Allied Market Research [13], the 2027 global cosmetic market size is estimated to achieve USD 463.5 billion, growing at a CAGR of 5.3%. As natural cosmetics are considered unique products, influencing the purchasing behavior of consumers, their global market value is increasing and is expected to reach USD 54.5 billion by 2027 [14].

As Generation Y has grown more integrated into the market, they have become a huge player in the cosmetics industry. In order to attract new customers and maintain current users committed to particular brands, global cosmetic industries concentrate their strategies on product innovation. At present, perceptions towards the use of cosmetics are growing within the population. Women express great interest in personal care. Additionally, professional women, particularly those with higher earnings, are often interested in purchasing premium skincare products. Consumers appear to be willing to pay higher prices for greater quality and benefits of the products, such as antiaging, multi-functions, and whitening. Nowadays, men even prefer to treat personal grooming as a requirement instead of just a luxury [15]. According to Euromonitor, in Malaysia, the men's grooming demand has increased by 8% from MYR 935 million in 2017 to MYR 1 billion in 2018. This market is predicted to achieve MYR 157 billion by 2023, with an annual compound growth rate of 9% [16].

In Malaysia, over 60,000 forms of cosmetics are available in the local market. Malaysian cosmetics companies appear to be using a competitive strategy to purchase costly products in installments and encourage a high discount for branded cosmetics. Consequently, the marketing of branded products is growing in order to obtain the maximum degree of visibility for such products. In addition, an extraordinary discount is provided on premium cosmetics, which corresponds to sustaining the demand for cosmetics among consumers, as well as other cosmetic brands [17]. Malaysian customers are currently influenced by offers of market promotion, and they are looking for cosmetics whenever a discount is available, particularly for premium products. Admittedly, Malaysian customers tend to purchase beauty products from top brands that are specifically promoted to enhance their youthful appearance. An enormous amount of brand cosmetics is highly competitive with new brands, as well as other brands available in beauty shops, promotional stores, and pharmacies. The most efficient ways to improve the purchasing rate of cosmetic products among consumers are advertisements in the media, newspapers, and magazines [18].

4. Nanotechnology in Cosmetics

Nanotechnology is a comparatively modern field in the cosmetic industry. Presently, nanotechnology is indeed important as a platform for creating science-based alternatives for advanced therapeutics and cosmetics, resolving antiaging challenges, and enhancing well-being. Nanotechnology is described as an investigation of substances on a molecular and atomic scale. Nanotechnology essentially deals with objects and structures that are calibrated on a nanometer scale [19], such as one billionth of a meter (10^{-9}), which refers to a nanometer (nm). In fact, the average thickness of human hair is about 100 μm , and the diameter of an influenza virus is 100 nm. Moreover, an organic molecule of two carbon is 0.15 nm, whereas a bacterium measures 10 μm . Therefore, one can envision the dimensions used in nanotechnology. The commercialization of nanoparticles in cosmetics has been dominated by L'Oreal, which is devoting USD 600 million to patent the application of nanoparticles. To date, L'Oreal is the largest holder of nanocosmetic patents, followed by Procter & Gamble, Henkel, Unilever, etc. [20]. Moreover, there are countless published papers regarding the role of nanotechnology in cosmetics, as illustrated in Figure 1, in which the data is obtained from Science Direct from 2010 to 2022.

In the 1950s, the physicist Richard Feynman, known as "The Father of Nanotechnology", introduced the concept of the power to manipulate atoms and molecules, which was believed to result in microscopic components that became invisible to the naked eye. In 1974, Professor Norio Taniguchi from the University of Tokyo identified the term "Nanotechnology" as a method of deforming, consolidating, and separating a material molecule by molecule or atom by atom. It is eventually discovered that matter has unique nanoscale properties. The small particle size of nanoparticles (nm) leads to effective penetration into the skin compared to their bulk counterparts. Therefore, nanotechnology is anticipated to be the fastest-developing field for the maintenance of healthy skin [21].

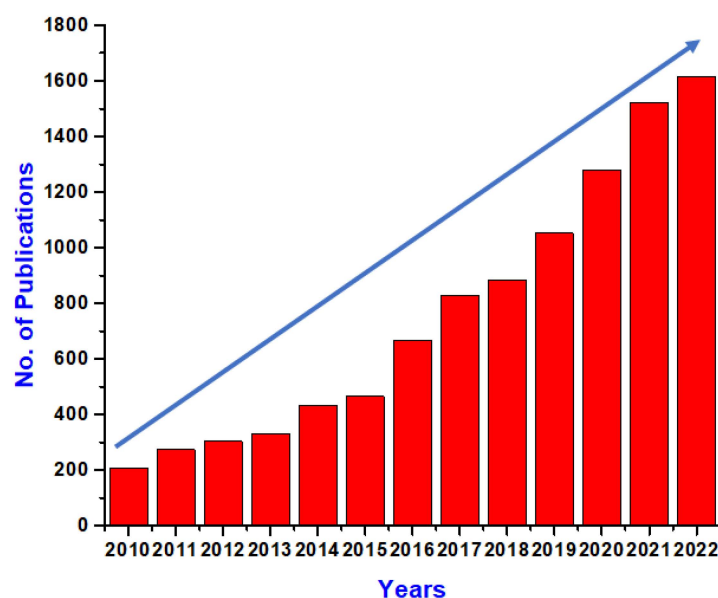


Figure 1. Publication trends (from 2010 to 2022) on the role of nanotechnology in cosmetics.

Nanotechnology has been used in the cosmetics industry for almost 40 years [22]. Figure 2 provides an overview of why nanotechnology has been used as an important ingredient in cosmetics.

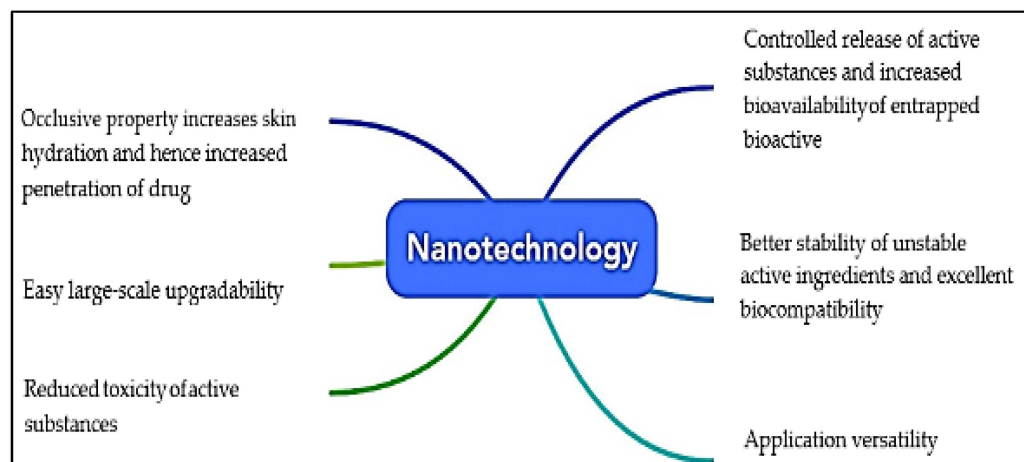


Figure 2. Benefits of nanotechnology in skincare products [23].

4.1. Nanomaterials on Skin

Over the last few decades, nanomaterial-based products have been growing and targeting diverse industries, such as cosmetics, pharmaceuticals, and dermatology. Nanomaterials are widely used in cosmetics, such as in the preparation of conditioners, hair serums, moisturizing creams, hair-repairing shampoos, skin-whitening creams, and anti-wrinkle creams [24]. Cosmeceuticals are cosmetic products that contain naturally active materials and medicinal properties which are transferred onto the skin [25]. These have been used as cosmetics since they have been proven to enhance appearance. Cosmeceutical products provide significant medicinal effects on the skin and are used to treat various symptoms, including acne, dry skin, photoaging, poor appearance, black spots, and hyperpigmentation. Nanocosmeceuticals offer enhanced biocompatibility and stability, as well as a prolonged effect and the potential to improve the payload distribution to the skin. Multiple kinds of nanomaterials, such as niosomes, liposomes, nanostructured lipid carriers (NLC), solid lipid nanoparticles (SLN), gold nanoparticles, nanoemulsions, and

polymeric nanoparticles, have been proposed for topical product distribution since they are made from biocompatible materials [26]. Their application in personal care products benefits from the potential to regulate the distribution of cosmeceuticals with the formation of a thin film, along with more precise delivery into the skin. Additionally, skin aging is a complex process that can be induced exogenously and endogenously [27]. However, about 90% of skin aging is activated by UV radiation exposure.

Another factor affecting the progression of the aging process is lifestyle, such as drinking, smoking, and sleeping, as well as environmental influences (pollution) and malnutrition. Dry texture, the texture of wrinkles, and loss of skin elasticity are the first symptoms of skin aging. The first symptoms of skin aging can be prevented and/or delayed nowadays. For the topical delivery of active ingredients, conventional topical formulations (suspensions, solutions, gels, aerosols, powder, and emulsion) are acceptable [27]. However, all these formulations have certain restrictions and can impair the treatment's safety and/or efficacy. To overcome these constraints, a variety of nanomaterials for active-ingredient delivery have been developed. The continuous development of skin products with active ingredients utilizing nanomaterials in health and cosmetic industries creates new possibilities with favorable impacts on society and industries [28]. To promote product innovation by creating nanoproducts, the loading of active pharmaceutical ingredients (APIs) through nano-sized drug delivery systems is currently being exploited. The efficacy of nanoproducts utilized for API delivery into the skin, such as nanocosmeceuticals and nanopharmaceuticals, has previously been demonstrated, as numerous skincare products are already on the market.

The primary challenge in delivering APIs through the skin is overcoming the many physiological layers with different polarities. It is well recognized that skin defends the body from xenobiotics, which can include not just pathogens and hazardous toxins but also drugs, while somehow ensuring that physiological fluids are expelled for homeostasis. Because skin penetration reduces API absorption, the bioavailability of APIs administered topically is lesser than that of intravenous and oral routes. Numerous kinds of nanoparticles have been suggested to resolve the difficulties of API skin administration. Furthermore, Otlati et al. [27] claim that various APIs may be utilized in cosmetic products to prevent, delay, and, if feasible, cure skin aging. Figure 3 summarizes an illustration of nanomaterials used for loading numerous APIs and their application purposes [28].

4.2. Formation of Nanoemulsions

Nanoemulsions are colloidal dispersions of water-in-oil or oil-in-water, containing droplets with diameters ranging from a few to 200 nm. An improvement in nanoemulsion-related patent protection activities indicates a growing industrial interest in nanoemulsions [29]. Because of the tiny size of the droplets, they can provide favorable stability and optical, rheological, and ingredient delivery characteristics that are greater than conventional emulsions. Transparency and stability are characteristics of nanoemulsions. Furthermore, their formation increases the water content of the stratum corneum, indicating their efficacy as a moisturizer. Musazzi et al. [30] claim that nanoemulsions may substantially change the permeation profiles of molecules due to their physicochemical characteristics, and specifically, oil/water nanoemulsions greatly enhance the permeation profiles of polar ingredients when compared to conventional emulsions. Compared to conventional emulsions, nanoemulsions act as effective carriers for different bioactive compounds with enhanced properties, such as enhanced bioavailability, physical stability, and high optical consistency [31].

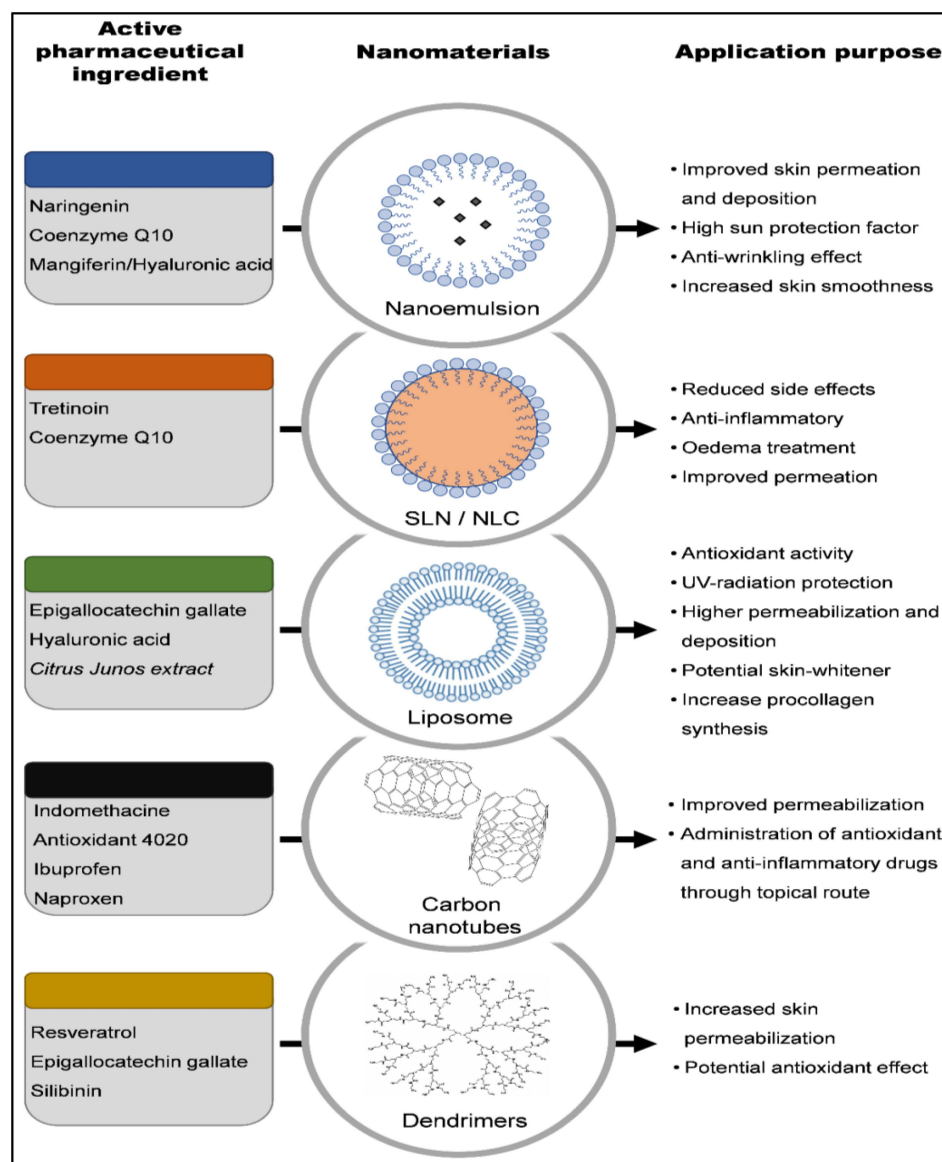


Figure 3. Illustration of nanomaterials that have been utilized to encapsulate a variety of active pharmaceutical ingredients, along with their applications [28]. SLN: Solid lipid nanoparticles; NLC: nanostructured lipid carriers.

On the other hand, nanoemulsions have a lipophilic interior and are particularly desirable for the transport of hydrophobic substances under aqueous conditions [32]. Compared to nanocapsules, nanoemulsions have a greater ability to penetrate the skin and spread on it. This is possibly due to their lack of polymers and flexibility; this interacts with the stratum corneum. Nanoemulsions encourage water-immiscible active compounds, including lipids, antioxidants, and retinol, to penetrate more intensively into the target tissues and increase their effective concentrations.

Penetration of Nanoemulsion Systems into the Skin

The critical challenge with topical drug delivery is the skin barrier, which prevents the drug from penetrating into the systemic circulation. This barrier can be significantly resolved by nanoemulsion-based topical drug delivery. Sweat ducts, hair follicles, and directly through the stratum corneum are the three most prevalent pathways for drugs to penetrate the skin. In nanoemulsions, small-sized nanoparticles may readily flow across the pores, as illustrated in Figure 4. In addition, the hydrophilic and hydrophobic units make it

easier to penetrate both the hydrophobic stratum corneum and the hydrophilic sweat ducts. Nanoemulsion can be used effectively against psoriasis and dermatitis [33]. Positively charged nanoemulsions interact more to penetrate through the negatively charged tissue and thus have been proven to provide greater performance and penetration than negatively charged nanoemulsions [34].

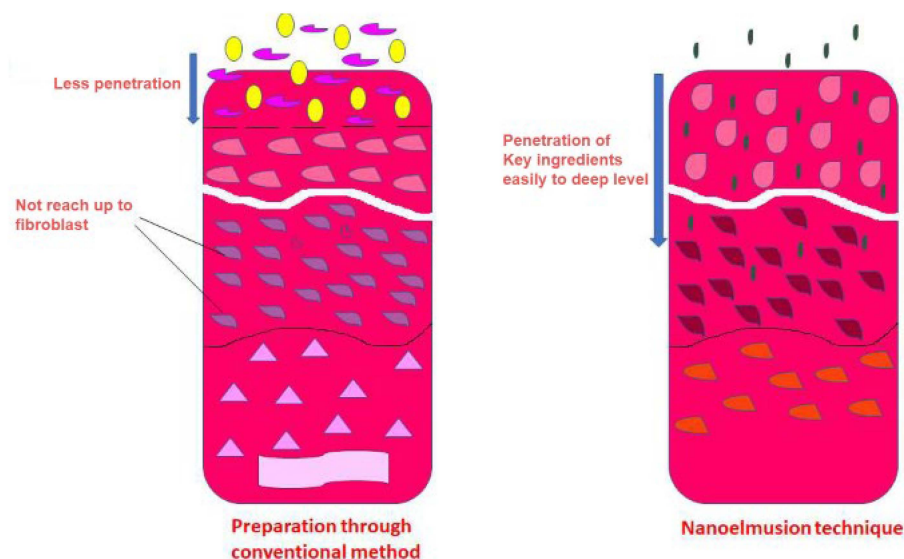


Figure 4. Comparison of nanoemulsions with the conventional transdermal formulations in the case of crossing skin barrier [35].

4.3. Formation of Micelle Nanoparticles

Micelle is a simple structure commonly created by amphiphiles in aqueous solutions. Typically, the particle size of micelles is in the range of 5–50 nm. They represent a group of associations or amphiphilic colloids that instantaneously form amphiphilic or surface-active agents in certain temperatures and concentrations, of which the molecules consist of two clearly distinct regions with opposite affinities to a given solvent. At low concentrations in an aqueous medium, these amphiphilic molecules exist separately. However, aggregation takes place when their concentration is raised to a specific range. The critical micelle concentration (CMC) is the concentration at which the monomeric amphiphile produces micelles [36].

The aggregation number of a micelle is the number of individual molecules that constitute the micelles. The formation of micelles is driven by the lowering of free energy in the system, resulting in the removal of hydrophobic segments from the aqueous environment and the re-establishment of the hydrogen bond network in water. The formation of Van der Waals attraction between hydrophobic blocks in the center of the produced micelles leads to an increase in energy gain [37]. The hydrophobic regions of amphiphilic molecules create the micelle's core, while the hydrophilic portions create the micelle's shell [38]. Micelles, when used as drug carriers in aqueous conditions, solubilize molecules of weakly soluble nonpolar pharmaceuticals within the micelle core, whereas polar molecules are adsorbed in the micelle shell. Drug carrier micelles have several benefits, such as [36]

- i. The use of micelle-forming amphiphiles in drug solubilization leads to an increased bioavailability of sparingly soluble drugs and water solubility;
- ii. Toxicity and other negative consequences are minimized;
- iii. Permeability across physiological barriers is enhanced, and there are promising improvements in drug biodistribution;
- iv. The use of specific amphiphilic substances could also contribute to the characteristic of micelles' blood having an extended half-life;

- v. Due to their small size, micelles can spontaneously permeate the interstitium with leaky vasculature due to the increased permeability and retention (EPR) effect in bodily compartments;
- vi. The drug in micellar form is adequately shielded from biological surround inactivation and has no adverse side effects on tissues and non-target organs.

Micellar Nanoparticle Formulation

Micellar nanoparticles are formulations based on nanotechnology that achieve high levels of transdermal therapy and can form very fine nanoparticles reaching 10 nm [39]. The formulation provides an excellent and efficient delivery system capable of incorporating a variety of lipophilic components with varying physicochemical characteristics, like a nano-vehicle, to efficiently implement the lipophilic constituent to the skin while shielding the components from effortless decomposition caused by biological reactions within the human body [40]. In comparison to other conventional nanocarriers, such as niosomes, ethosomes, and liposomes, which face challenges such as high production costs, poor bioactive encapsulation performance, and greater particle size, this nanocarrier has emerged as among the most recent nanotechnology-based transdermal drug delivery [41]. Furthermore, one of the efficient micellar formulation properties is the capacity of the nanoemulsion system to be created as a transparent solution, reflecting tiny micelles distributed throughout the aqueous processes. The transparency diagram in Figure 5 represents the tiny micelles distributed throughout the nanoemulsion system. Saberi et al. [42] said that the tiny micelle particle size does not scatter light severely due to its size being smaller than the wavelength of light, which results in the development of a transparent solution.

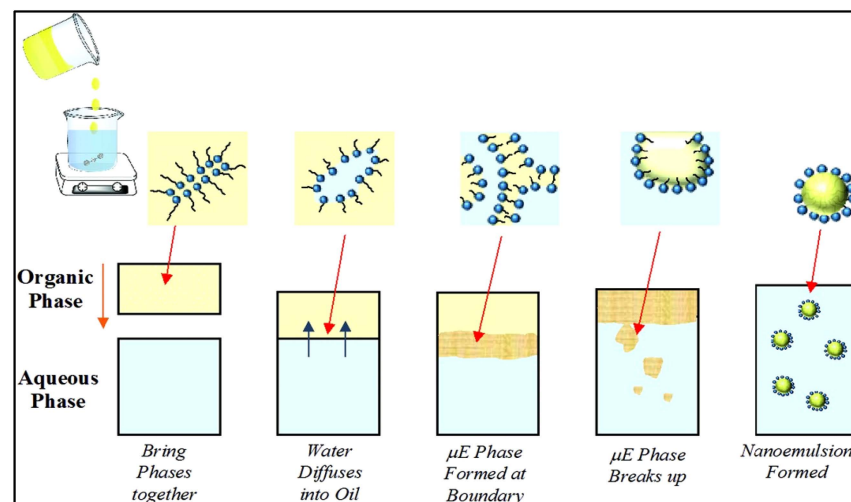


Figure 5. Mechanism of micelle formation in a nanoemulsion system utilizing the spontaneous emulsification method [43].

Surfactants play a critical role in the development of a successful, innovative micellar formulation, which is dependent on the synthesis of fine mean micelle particle diameters and the spontaneous emulsification approach. By easily reducing the interfacial stress between oil and the aqueous phase, the smaller diameters of micelles can be facilitated by surfactants. Furthermore, by dispersing one liquid into another immiscible liquid phase using low- and high-energy approaches, nanoemulsions can generate micellar nanoparticles [43].

In terms of a nanosystem's capability to transform smaller nanoparticle sizes from 10 to 200 nm, O/W nanoemulsion has outstanding cosmetic-based properties when compared to other emulsions. Furthermore, this enables uniform distribution on the skin, a good aesthetic character, high stability, and improved active delivery properties, surface area, and skin feels [44]. To obtain the maximum efficacy of cosmetics, a certain penetration

of the active component integrated with nanotechnology into the skin is required. This is due to the fact that the efficacy of penetration is affected by a variety of characteristics, such as lipophilicity, molecular size, and degree of ionization. An additional critical feature of nanoemulsion-dependent cosmeceuticals is the tiny micellar nanoparticle scale, which has the kinetic stability and strong thermodynamic stability of the cosmetic formulation against sedimentation, flocculation, and Ostwald ripening.

Ostwald ripening plays a critical role in facilitating the instability of O/W nanoemulsions owing to micelle dispersion from small to large droplets through a continuous phase that is known as an aqueous solution [45]. As a result, tiny micelles deform to create significant micelles, jeopardizing the cosmetic formulation's long-term stability, which can be a major concern in the development of high-quality, as well as effective, cosmetic products [46]. The oil phase plays a crucial role as a component in the creation of micellar nanoparticles in nanoemulsions, where it is essential for the solubilization of the lipophilic active components in cosmetic formulations [47]. Only some types of oil are appropriate for developing cosmetic formulations. The oil phase often contains the lipophilic cosmetic's bioactive ingredients, such as hydrophobic nutraceuticals, nutrients, vitamins, colors, essential oils, antioxidants or antibacterial agents, and carrier oils. Carrier oils are typically used to promote or enhance the stability of a nanoemulsion system in micellar development [44].

5. Natural Cosmetic in Marketing

The concept of using natural products and additives has been increasing drastically [48]. This is more prominent when it comes to cosmetic products. The increasing popularity of natural ingredients is mainly due to the adverse effects of synthetic materials on the environment and health. Marketing patterns are currently moving towards natural cosmetic solutions that contribute to a healthier lifestyle and link the use of cosmetic products to healthy eating habits. Nowadays, makeup is also a natural part of everyday life, where it acts as a tool for confident looks. From here, we can claim that people are more interested in the search for natural skincare to enhance their appearance [49].

The concept 'natural' refers to any chemical substance that occurs naturally from [50]:

- i. Processed;
- ii. Unprocessed—only by naturally, mechanical, manual, naturally derived solvent, or gravitational processes, dissolving in steam or water, heating merely to separate water, flotation and;
- iii. Extracted from the air in every way possible.

Petroleum and petroleum-derived ingredients are not included in the word "natural". The term "naturally derived ingredient" is defined as follows [50]:

- i. Any component derived from a plant, mineral, animal, or microorganism, which is the raw material that has been chemically treated;
- ii. Any substance in which the basic material is of plant, mineral, animal, or microbial origin and has been chemically treated and mixed with other ingredients, with the exception of fossil fuel-derived and petroleum substances;
- iii. Ingredients are generated from a bio-manufactured and plant feedstock by processes such as saponification, fermentation, esterification, or condensation to facilitate the efficient, economical, sustainable, or biodegradable creation of ingredients.

Furthermore, the global market value of natural cosmetic products is expected to quadruple from 2018 to 2027, reaching around \$54.5 billion. This demonstrates the growing importance of the natural and organic cosmetics industry. The distinction is visible in the definition. To be considered natural, the product must meet non-toxic requirements for components and manufacture. Because the natural beauty industry is not rigorously regulated, the disparity between private standards and official interpretations creates a potentially dangerous loophole for consumers.

6. Natural Ingredients in Cosmetics

The incorporation of nature in beauty products has been observed since 10,000–3000 B.CE [51]. According to Mohd-Nasir [52], the demand for natural and safe resources for cosmetics came to light in the 20th century due to the awareness of the drawbacks offered by artificial or synthetic ingredients. There is an abundance of natural sources that are used as main ingredients in skincare products nowadays, especially by leading brands such as SKII, Mary Kay, and L’Oreal, which set the trend. Table 1 reviews several natural resources, including plant extracts, plant oils, and individual compounds, that are often used in cosmetics to enhance the effectiveness of the products, as well as to follow current trends in natural cosmetics.

Table 1. Natural ingredient examples commonly used in cosmetics.

Natural Ingredients	Overview	Active Constituent	Benefits to Skin	Ref.
Plant extracts				
Tsubaki flower	<ol style="list-style-type: none"> i. Scientific name: <i>Camellia japonica</i> ii. Popular as ornamental plant and has health-enhancing properties iii. Oil, fruit, and leaf of the plant also provide numerous biological activities 	<ol style="list-style-type: none"> i. Rich source of antioxidants, vitamins, phytosqualene, omega-6 	<ol style="list-style-type: none"> i. Antipollution effect to prevent skin aging due to air pollutants ii. Improve skin barrier iii. Antiallergic iv. Anti-inflammatory v. Antiacne vi. Antioxidant protection vii. Boosting skin hydration 	[53–55]
Chamomile flower	<ol style="list-style-type: none"> i. Scientific name: <i>Matricaria recuitta chamomilla</i> ii. Traditional uses include treatment for stomachache, irritable bowel syndrome, insomnia iii. Can control skin damage, eczema 	<ol style="list-style-type: none"> i. Phenolic acids ii. Flavonoids (apigenin, quercetin, patuletin, luteolin) iii. Coumarin 	<ol style="list-style-type: none"> i. Anti-inflammatory, ease skin irritation 	[56–59]
Licorice roots	<ol style="list-style-type: none"> i. Scientific name: <i>Glycyrrhiza glabra</i> ii. The extract is bright yellow interior, fibrous, soft iii. Has been used as a common remedy in domestic treatments against numerous bacterial infections of antiquity, i.e., alleviating pain, nourishing, alleviating coughing, removing phlegm 	<ol style="list-style-type: none"> i. Liquiritigenin, glycyrrhizin, licochalcone A, glabridin, licochalcone E ii. Comprises over 20 triterpene oils and almost 300 flavonoids 	<ol style="list-style-type: none"> i. Skin lightening ii. Anti-inflammatory effect, reduce redness of skin and post-inflammation hyperpigmentation iii. Induces depigmentation by dispersion and elimination of melanin 	[60–63]
Plant oils				
Peppermint oil	<ol style="list-style-type: none"> i. Derived from <i>Mentha piperita</i> L. ii. Frequently used as a fragrance in cosmetics, soaps, and seasoning since it has a minty, cooling, and refreshing sensation iii. Has aromatherapy effect 	<ol style="list-style-type: none"> i. Menthol (33–55%) ii. Methone (14–33%) iii. Neomenthol iv. Iso-methone v. Others: β-pinene, 1,8-cineole, methofuran, methyl acetate, limonene, isomenthone, α-pinene, trans-sabinene hydrate, pulegone, germacrene 	<ol style="list-style-type: none"> i. Anti-inflammatory ii. Antibacterial, especially for reducing acne iii. Antiseptic iv. Naturally cleanse skin v. Cooling effect for soothing irritation and inflammation due to acne vi. Hydration and reduce sunburn vii. Contain natural sun protection factor (SPF) 	[64–67]

Table 1. Cont.

Natural Ingredients	Overview	Active Constituent	Benefits to Skin	Ref.
Rose oil	<ul style="list-style-type: none"> i. Extracted from <i>Rose x. Damascene</i> Mill flower ii. Usually use as fragrance in skincare 	<ul style="list-style-type: none"> i. B-citronellol (14.5–47.5%) ii. Nonadecane (10.5–40.5%) iii. Geraniol (5.5–18%) iv. Terpenes, glycosides, flavonoids, anthocyanins 	<ul style="list-style-type: none"> i. Anticonvulsant, analgesic, hypnotic, antioxidant ii. Efficient in moisturizing dry skin iii. Prevention of acne iv. Exfoliates the skin v. Protect skin from bacterial infections 	[68–70]
<i>Helichrysum italicum</i> oil	<ul style="list-style-type: none"> i. Known as immortelle ii. Bright yellow-colored inflorescences 	<ul style="list-style-type: none"> i. α-pipene ii. Neryl-acetate iii. Nerol iv. α and γ-curcumin v. Geranyl acetate 	<ul style="list-style-type: none"> i. Soothing agent to reduce skin irritation and soothes redness ii. Skin repair and healing by producing collagen and elastin iii. Allergy counteraction iv. Wrinkle, dark spot, acne reduction 	[71,72]
Individual compound				
Lignin	<ul style="list-style-type: none"> i. Most abundant polyphenol in nature, recover from pulp and paper industry waste ii. Main component in plant cell wall 	Lignin	<ul style="list-style-type: none"> i. UV shielding activity to prevent UV absorption into skin and cause sunburn ii. Antiaging iii. Antioxidant iv. Biocompatibility v. Antimicrobial 	[73]
Hyaluronic acid (HA)	<ul style="list-style-type: none"> i. In 1934, glycosaminoglycan (GAG) from the vitreous fluid of the bovine eye for the first time and called it “hyaluronic acid” (derived from uronic acid and hyaloid [vitreous]) ii. Various organs and tissues can generate HA naturally iii. Also generated by microbial fermentation (<i>S. zooepidemicus</i>, <i>B. subtilis</i>, <i>E. coli</i>) iv. Molecular weight is claimed to be regulated by the concentration of UDP-N-acetylglucosamine v. HA encloses immense amount of water results in low-concentration and high-viscosity solutions vi. Gradual decrease HA throughout the skin result in aging process 	HA is a non-sulfate Glycosaminoglycan or mucopolysaccharide consisting of D-glucuronic acid and N-acetyl-D-glucosamine linked by a glucuronic bond of β (1→3)	<ul style="list-style-type: none"> i. Antiaging ii. Skin-protective iii. Restore skin moisture balance iv. Activate skin’s natural HA v. Stimulate cellular regeneration and collagen formation vi. Used broadly through injections as a filler to rebuild the age-dependent loss of the facial skin volume 	[74–78]

7. Application of Nanotechnology-Incorporated Natural Ingredients

Natural raw materials, especially plant extracts, have been identified as rich in beneficial properties when applied to the skin. However, they are chemically unstable and face adverse reactions during the formulation stage, which may cause a reduction in biological effects. Nanoencapsulation of phytochemicals is proven to prolong stability,

enhance solubility, as well as preserve the therapeutic benefits of the extracts [79]. Additionally, nanoencapsulation improves local and controlled skin delivery of ingredients and enhances the sensory properties of cosmetic products [80]. These three main advantages of nanoencapsulation of natural substances support and trigger the increasing trend of nanotechnology application in natural cosmetics. Plant-derived nanoparticles made of biocompatible macromolecules can be employed as low-cost, long-term, and renewable drug delivery systems. These nanostructures are composed of a wide range of materials, including lipids, proteins, polysaccharides, and many more, either as individuals or as a combination [81].

Several scientific studies have validated the efficacy of nanocosmetics in delivering the benefits of natural substances to the target area. Sugumar et al. reported the development of nanoemulgel by formulating oil-in-water (O/W) nanoemulsions containing mangosteen extract to deliver its antiviral, antifungal, antioxidant, antitumoral, and antibacterial bioactivities. They found that the nanoemulgel with mangosteen micelles successfully penetrated the skin layer, delivering more than 95% of the total mangosteen content [82].

Technical lignin is well-known for its antioxidant and UV protection abilities, and it is safe to use in cosmetic preparations and sunscreens as it shows low toxicity toward animal cell lines [83]. The conversion of altered kraft lignin to nanoparticles significantly enhances UV absorption properties in sunscreen, especially sun protection factor (SPF) and UVA/UVB transmittance [84]. The modified kraft lignin (containing CatLignins) sunscreen has lower UV transmittance (0.5–3.8%) compared to commercial sunscreens with SPF 15 (2.7–51.1%). This sunscreen active is more environmentally friendly and protects the skin from unwanted side effects [85]. In fact, there are a lot of commercialized products in the market which implement nanoparticles for value and benefits enhancement. Table 2 summarizes some of the examples of nanoparticle-based commercialized cosmetic products reviewed by Faria-Silva et al. [80].

Table 2. Example of commercialized natural nanocosmetics [80].

Nanotechnology	Commercial Product	Industry	Plant-Based Ingredients	Benefits
Liposomes	Advanced Night Repair Protective Cream	Estée Lauder	<i>Musa cola acuminata</i> , <i>Anthemis nobilis</i> extracts	Skin repair
	Capture Totale Le Serum	Dior	Longoza, limonene, rye seed extract, rice protein, lecithin	Antiwrinkle, skin brightening, sunscreen
	Hydrance optimale Cream	Avène	<i>Carthamus tinctorius</i> seed, <i>Glycine soja</i> seed extract	Moisturizer
	Hydra Radiance Cream	Avon	<i>Citrus paradisi</i> peel oil, hydrolyzed <i>Opuntia Ficus</i> extract, <i>Coenochloris signiensis</i> extract	Vitamin enrichment
	Russell Organics Liposome Concentrate	Russell Organics	Vegetable oils and floral water	Hydrating and rejuvenating lotion
	Cleansing Milk	Ecco Bella	<i>Aloe vera barbadensis</i> , <i>Achillea millefolium</i> , <i>Thyme thymus vulgaris</i> , <i>Calendula officinalis</i> , <i>Matricaria chamomilla</i> L., <i>Arctium majus</i> root, <i>Helianthus annuus</i> seed oil	Cleanser
Niosomes	Antiage response cream	Simply Man Match	Pomegranate seed oil, ginseng extract avocado oil, mineral salts	Antiaging
	MayuNiosome Base cream	Laon Cosmetics	Ginseng, saponins	Brightening moisturizer
	Identik Masque Floral Repair	Identik	<i>Punica granatum</i> seed extract, hydrolyzed yeast extract	Hair repair masque

Table 2. Cont.

Nanotechnology	Commercial Product	Industry	Plant-Based Ingredients	Benefits
SLN and NLC	Allure Body Cream	Chanel	Squalene, linalool, tocopheryl acetate, hexyl cinnamal, limonene, ascorbic acid, citric acid	Moisturizer
	Phyto NLC Active SirehEmas Cell Repair Cream	SirehEmas	Olive oil, <i>Cucumis sectious</i> extract, <i>Curcuma xanthorrhiza</i> extract	Antiwrinkle cream, hyperpigmentation reducing
	Cutanova NanoVital Q10 and NanoRepair Q10 Creams	Dr. Rimpler	CoQ10, <i>Cannabis sativa</i> seed oil, hydrolyzed wheat protein, soy protein, <i>Zea mays</i> oil, panthenol, ursolic acid	Antiaging, UV protectant
	Regeneration cream Intensiv	Scholl	<i>Lilium candidum</i> , <i>Crataegus laevigata</i>	Regenerating, wrinkles smoother
	NLC Deep Effect Eye Serum, Repair Cream, Reconstruction Cream and Reconstruction Serum	Beate Johnem	Mafane extract	Antiaging
Nanoemulsions	Olivenol Anti Falten Pftegekonzentrat Cream	Dr. Theiss	Olive oil, <i>Acacia senegal</i>	Antiaging
	Bepanthol Ultra FacialProtect Cream	Bayer HealthCare	Ceramides, lecithin	Antiaging, moisturizing
	Korres Red Vine Hair Sun Protection Spray	Korres	Polyphenols, <i>Helianthus annuus</i> seed extract	Prevents hair color from fading away
	Phyto-Endorphin Hand Cream	Rhonda Allison	<i>Vitex agnus-castus</i> casticin extract, <i>Bellis perennis</i> flower extract, lecithin, cholesterol, corn oil, soybean oil, sweet orange peel oil, sweet almond oil	Revitalizing moisturizer
Nanospheres	Celazome Eye Treat Cream	Celazome	Shea butter, olive oil, squalene, green tea extract, vitamin E	Antiaging
	Celazome O-Plex Target Acne Spot Treatment Cream	Celazome	Tea tree oil, Origanum complex	Antiacne
Nanocapsules	Oligo DX Cellulite Treatment Cream	DS Labs	<i>Nelumbo nucifera</i> extract, acacia gum extract, ivy extract	Body firming
	Eye Contour Nanolift Cream	Euoko	<i>Rhodiola rosea</i> extract, sugar beet extract	Antiwrinkle
	Hydra Flash Bronzer Daily Cream	Lancôme	Vitamin C, vitamin E, Aloe water	Antioxidant, hydrating moisturizer
Gold nanoparticles	NanoGold Energizing Cream	Chantecaille	Vitamin C, vitamin E, algae extract, plantago extracts	Rejuvenating, antiaging
	Orogold 24 K Nano Ultra Silk Serum	Orogold Restores	<i>Helianthus annuus</i> seed oil, <i>Laminaria japonica</i> extract, <i>Chlorella vulgaris</i> extract, <i>Laminaria digitata</i> extract, <i>Helichrysum arenarium</i> extract, <i>Citrus aurantifolia</i> peel extract, <i>Rosmarinus officinalis</i> leaf extract	Prevent moisture loss, improves wrinkles and fine lines, maintains healthy skin
	Tony Moly Nanogold BB Cream	Tony Moly	<i>Centella asiatica</i> extract, madecasoides, tea tree	Skin whitening, antiaging
Silver nanoparticles	Cosil Nano Beauty Soap	Natural Korea	Arbutin, Aloe vera	Cleanser, detoxifier, exfoliator
Silica nanoparticles	Lancôme Renergie Microlift Cream	Lancôme	Soy protein	Antiwrinkle

8. Commercialized Nanotechnology-Based Micellar Cosmetics

In a wide range of product categories, nanoparticle-based micellar products in the cosmetic arena are becoming prominent. Furthermore, this nanotechnology has been implemented by numerous multinational and local companies as a ground-breaking technique to provide their beauty products with efficacy and superior quality. The nanoemulsion system plays a significant role in the formation of bioactive component-enriched micellar nanoparticles as a possible vector for a stable cosmeceutical delivery system.

8.1. L'Oreal

The current commercial cosmetic products that utilize micellar nanoparticles technology are presented in this section. There have been a huge variety of personal care products that were developed based on nanotechnology and claimed to be a perfect skincare solution. In fact, L'Oreal Paris appeared to be the globally most successful skincare brand. Based on Statista Research Department [86] analysis, statistics between 2010 and 2021 show that the L'Oreal Group increased its consolidated sales by approximately 10 billion US dollars worldwide. After years of constant growth, the company managed to generate close to 29.8 billion US dollars in global sales in 2019.

8.2. Garnier

Micellar Water by the Garnier brand is used to remove makeup, cleanse, and refresh the skin. Without intense rubbing, the micelles absorb and extract oil, dirt, and makeup using micellar technology, leaving the skin clean without over-drying it. Garnier Micellar Water is formulated without oil, alcohol, or scent and is effective for all types of skin. Furthermore, Micellar Cleaning Water has received over 10,000 five-star reviews and has been awarded 23 beauty awards. Garnier reports that every four seconds, one bottle of Micellar Cleaning Water is purchased [87].

8.3. NK Age-Reverse

In Malaysia, some cosmetic industries are very interested in creating awareness of the importance of non-toxic cosmetics and skincare in order to provide Malaysian women with skincare and cosmetic products that are non-toxic, healthy, safer, and based on local and imported natural ingredients as much as possible. A cosmetic product that satisfies almost all the above-discussed criteria, mainly with natural ingredients, has been established by SHE Empire Sdn. Bhd. in Malaysia [88]. They have launched a brand named "NK Age-Reverse", which introduced cosmetic segments focused on micellar nanoparticles. It is a high-flying brand that utilizes micellar nanoparticles technology in numerous cosmetic items produced through research and development approaches. In 2018, they unveiled and commercialized their "Micellar Series" [89]. Through the use of micelle nanoparticles in nanoemulsion technology, the Micellar Series has achieved a great review by commercializing two of its products, which are a micellar-based facial cleanser and an energy water mist. The micellar-based cleanser is 3 in 1 purpose; it is an effective way to remove makeup and grime from the face with an infusion of bioactive components-micelles; as a result, it produces unique skin improvements after cleansing. The commercialized micellar-based cleanser facial mist acts as an expert treatment for scars, antiaging, acne, and pigmentation. In 2020, they enhanced the formulation of the micellar water in the NK Age-Reverse cleanser with premium ingredients and functions. This increased the effectiveness of face washing and makeup removal up to five times more than regular washing. Additionally, the combination of the use of the cleanser and water mist could moisturise the face up to 20 times more than normal washing. Due to the fact that these products are based on the dispersion of various bioactive components via micellar nanoparticles, such as roselle, bee venom, hyaluronic acid, licorice roots, and essential oils (peppermint oil and rose oil), which are developed through the nanoemulsion system.

9. Regulatory Aspects of Nanocosmeceuticals

The rapid development of nanotechnology in cosmeceutical fields has raised concerns on safety issues and the potential toxic effect, especially on human health, since there is still a lack of toxicity studies [79]. The concerns are because of the following:

- i. The extremely small size and shape of nanoparticles allow them to easily move inside the human body and pass through membranes. This makes them able to access cells, bloodstream, tissues, and organs and, consequently, cause cell damage or death [90];
- ii. The physicochemical properties of nanomaterials are altered and associated with a larger surface-area-to-volume ratio. High reactivity and biological activities can be observed compared to larger particles, which increases free radicals, leads to oxidative damage and skin irritation, and causes toxicity in the human system [90];
- iii. High surfactant concentrations are used in nanocosmetics to ensure their stability, and active compound penetration can trigger skin irritation by affecting cells in the deep skin layer [91];
- iv. A common route of exposure to nanoparticles is inhalation, which may cause the substances to enter the pulmonary tract, travel to the brain, and gain access to the nervous system, blood and organs, leading to various adverse effects. Other modes of exposure are ingestion and through the skin [92].

There are several regulatory organizations that have published guidelines to cater to the safety aspect of nanocosmetics and assist the cosmetic industry, as well as academicians, researchers, etc. Table 3 summarizes important recommendations from main bodies [90,93–95]. These guidelines should be followed to prevent any adverse effects after the application of nanocosmeceutical products.

Table 3. Main regulations highlighting the safety of nanomaterial usage in cosmetics.

Regulatory Bodies	Rules	Guidance Document	Key Elements
Food and Drug Administration (FDA), United States	Food, Drug, and Cosmetic Act	Guidance for Industry Safety of Nanomaterials in Cosmetic Products	<p>Recommendations for safety assessment of nanomaterials should consider several important factors:</p> <ul style="list-style-type: none"> - Physicochemical properties - Route of exposure - Toxicological data of each nanomaterial
European Medicines Evaluation Agency (EMA), European Union	Council Directive 76/768/EEC	Scientific Committee on Consumer Safety (SCCS): Guidance on the Safety Assessment of Nanomaterials in Cosmetics	<p>Provide specific guidance on safety evaluation of nanomaterials used as cosmetic ingredients includes:</p> <ul style="list-style-type: none"> - Physicochemical characterization - Exposure assessment - Hazard identification and dose-response characterization - Risk assessment
International Cooperation on Cosmetics Regulation (ICCR)	-	Report of the ICCR Working Group—Safety Approaches to Nanomaterials in Cosmetics	<p>Provide experts' view on the key safety highlighting:</p> <ul style="list-style-type: none"> - Existing risk assessment pattern - Important physicochemical parameters of raw materials - Effect of formulation should be considered, as the bioavailability and toxicological profile of active compounds can be altered - Testing should include systematic absorption, local effects, route of exposure

10. Conclusions and Future Perspective

The nanotechnology-based cosmeceutical industry is expanding day by day and has the capacity to revolutionize the cosmeceutical market as the most potential technology of this era. In this study, innovative cosmeceutical delivery systems that have the potential to function as ‘new generation smart carrier systems’ were considered. Moreover, it has been proved that nanotechnology can be effectively used to enhance the safety, efficacy, stability, and aesthetic appeal of the product, which will ultimately lead to greater consumer compliance. Furthermore, it is important to deal with and produce nanoproductions in a manner that improves their value and also maintains consumer and environmental health. Natural products are demanded by consumers; however, they are also produced because of company-specific factors and regulations. Innovation in the cosmetics industry has been shown to be very significant and will most likely also develop in the future.

A further proposal or improvement that could be implemented in the natural cosmetic industry is the application of reverse micellar in their forthcoming products. This is due to the fact that reverse micelles are utilized in the selective separation and purification of biomolecules, as well as the production of nanoparticles. Reverse micelles are nanometer-sized droplets in an aqueous phase, stabilized by organic phase surfactants. Various organic and aqueous phases, as well as surfactants, have been used to create reverse micellar systems. Nanometer-sized aqueous systems are utilized to perform particular reactions that result in the creation of materials with regulated sizes and shapes. One of the factors for regulating the size of nanomaterials during their production is the size of reverse micelles. With increasing water concentration, the size of reverse micelles grows, resulting in larger nanoparticles. Reverse micelles are also employed as nanoreactors for nanoparticle production because they speed up the process and ensure more uniform dispersion of nanoparticles. Therefore, implementing reverse micelles in cosmetic products can enhance their effectiveness.

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