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PROSPECT OF NANOTECHNOLOGY IN COSMETICS: BENEFIT AND RISK ASSESSMENT

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ABSTRACT

Nanotechnology entered the field of cosmetics and consumer health products nearly 40 years ago with moisturizing creams that used liposome, a vesicle of phospholipid layers with an aqueous core. Nanotechnology in cosmetics involves the design, fabrication and improvement of physical properties by application of nanomaterials. Different terms are used in describing nanotechnology and nanomaterials: nanoparticles, nanoscience, nanotubes, nanoemulsions, nanosomes the list goes on. In cosmetics, "Nanomaterial" means an insoluble or biopersistant and intentionally manufactured material with one or more external dimensions, or an internal structure, fabricated on nanoscale". The global consumer market is dominated by wide range of nanomaterials, such as Carbon black (an intense cosmetic colorant) or synthetic amorphous silica (polymer filler in toothpaste or as anticoagulant in food powders) and a number of products such as UV-filters in sunscreens and anti-odour textiles. Nanomaterials in cosmetics include nanoemulsions, nanosomes and nanopigments commonly used in sunscreens, barrier skin creams and oral hygiene products. Nanotechnologically manufactured materials (so-called biocomposites) in toothpaste promote the natural tooth repair mechanism of saliva. In healthcare products, nanocapsules protect and transport active ingredients and enhance their effect. Nanoemulsions in cosmetics can increase the nutritious oil content of products such as high performance moisturisers, which may employ tiny pocket-like structures called nanosomes to help protect fragile ingredients from degrading. These nanoemulsions and nanosomes are soluble and break down upon application to the skin. However, nanotoxicological research expressed concern about the impact of manufacturing and use of nanomaterials on human health and environment with

possible evidence of nanotoxicity. Bacteriostatic silver nanoparticles used in socks to reduce foot odour are being released in the wash water causes destruction of natural ecosystem. Therefore, nanomaterials require a health risk assessment, which should be performed on a case-by-case basis, using pertinent information. Europe has already passed new laws that will require most nano-ingredients in sunscreens, cosmetics to face new safety testing and mandatory labelling.

Key words: anticoagulant, bacteriostatic, biocomposites, nanotubes, nanoemulsions, nanosomes, nanomaterials.

INTRODUCTION

Over 4000 years ago, prehistoric Egyptians, Greeks and Roman researchers were making use of nanotechnology in hair dye preparations. [1] From 1959 onwards, the concept of nanotechnology came into existence in different fields of sciences like biology, physics, chemistry, and engineering. [2] Also it has been entered in the field of cosmetics for instance; dermal preparations and other health products with moisturising creams prepared by using liposomes nearly existed 40 years ago. The prefix “Nano” from nanotechnology is a Greek word: “Nanos” – which means “little old man or dwarf”. Nanotechnology is a powerful new technology in which a material is reconstructed or engineered at an atomic and molecular level. One nanometer (nm) is one billionth, or 10^{-9} of a meter. According to the definition of National Nanotechnology Initiative in the US, the scale range of nanomaterial is 1 to 100 nm. [3] As nanoparticles are smaller in size, so, they exhibit different physiochemical properties. [4] Several types of cosmetics, sunscreens and personal care products which contain engineered nanomaterials are commercially available right now [5] in the global market. Many cosmetic formulations incorporate special nanoparticles that may be coated or may not be coated, provides sunscreen, tactile, light scattering and matte effects for the wearer. [6] Compared to their respective bulk materials, the nanomaterials may produce better self-cleaning or self-adhesive properties on a surface, increase the toughness of a particular material, improve resistance to friction & improve the quality of textiles, etc. There are also increased concerns about the impact of these nanomaterials in the environment and their possible impact on human health. The question of what is meant by nanotechnologies and nanomaterials [7] especially in food and cosmetics, remains one of the key issues in the debate between public authorities, industry, scientists, consumers, environmental groups and the media. The debate about what constitutes a nanomaterial has major implications for the entire risk governance cycle, including problem-framing, the assessment of risks and concerns, risk-benefit evaluation and suggestions for risk management options. As the design, development and production levels of self engineered nanomaterials will no doubt increase and intensify over the coming years, the question of their possible effects on health is of immediate concern.

Purpose of using nanometerials in cosmetics: The increased usage of nanomaterials in cosmetic products is indicative of the huge potential nanotechnology represents for the cosmetics industry and its consumers. A number of nanomaterial types are already in use, including nanoemulsions, and nanoparticles of minerals present in our natural environment, such as titanium dioxide (TiO2), zinc oxide (ZnO), alumina, silver, silicon dioxide, calcium fluoride and copper. The rationale for the use of nanomaterials in cosmetic products is, of course, that they offer added value in terms of product performance. The unique properties and behaviour of nanomaterials mean that nanotechnologies could profoundly transform industry and everyday life. In formulation of cosmetics, Titanium dioxide (TiO_2) and Zinc Oxide (ZnO) nanopigments are the main compounds used as highly efficient UV-filters, able to reflect and scatter the visible part of solar radiation while absorbing UV light. Given these properties, they are extensively used in sunscreens. Other examples of nanocosmetic products on the market include body firming lotion, bronzer, exfoliant scrub, eye liner, and styling gel, to name but a few. The nanomaterials found its next use as encapsulated carrier for topical delivery of photolabile and skin sensitizing compounds. [8] Liposomes and Niosomes are used in the cosmetic industry as delivery vehicles to improve;

- ✓ Direct interaction of sensitive agents with skin.
- ✓ The delayed release of sensitizing agents.
- ✓ Reduction in the amount of agents and additives.
- ✓ Increased lifespan and hence greater product acceptability [9, 10].

Nanocrystals, microemulsions, nanoemulsions, Fullerenes and dendrimers are also being explored in modern cosmetic and beauty care applications. Nanopigments are custom built to stay on the surface of the skin and are a major component of some sunscreens. Nanoemulsions are oil and water droplets often protecting fragile active ingredients (like vitamins). Unstable Vitamins can be suspended in nanoemulsions. The industry calls them nanocapsules, liposomes, lyphazones, etc. and nanoemulsions release the entrapped load upon contact with the skin on application. The next class of cosmetics includes fullerenes or fullersomes that are used as cages for active ingredients. Some fullerenes, specifically carbon based, might be hazardous when inhaled and they may oxidize some cells.

Types & preparation of nanoparticles mostly used in cosmetics

1. Solid lipid nanoparticle (SLN): These particles are prepared from extremely purified triglycerides, complex glycerides mixtures or even waxes by replacing the liquid lipid (oil) of an o/w emulsion by 0.1% (w/w) to 30% (w/w) of solid lipid or a blend of solid lipid (i.e. lipid that is solid at room temperature and also at body temperature) and stabilized by surfactant(s) with a preferred concentration of 0.5% (w/w) to 5% (w/w). [13] The mean particle size of SLN is in submicron range, ranging from 40 to 1000 nm.[11 ,12] There are different methods used for preparation like:[13]

1. Hot homogenization technique
2. Cold homogenization technique
3. Microemulsification- solidification technique
4. Multiple microemulsion- solidification
5. Ultrasonication or High speed homogenization
6. SLNs preparation using supercritical fluid.
7. SLNs by solvent emulsification / evaporation.
8. Double emulsion method.
9. Spray drying method

2. Nanostructured lipid carrier (NLC): Particles of Nanostructured Lipid carrier (NLC), the second generation of the lipid nanoparticle technology are prepared by using blends of solid lipids preferably in a ratio of 70:30 with liquid lipids (oils) in a ratio up to 99.9:0.1; in these mixtures a decrease in melting point as compared to the pure solid lipid is observed, because of oil content. The total solid content of NLC could be increased up to 95%. [10,12] Depending on the way of production and the composition of the lipid blend, different types of NLC are obtained with the active cosmetic agent, sandwiched between the fatty acid chains or in between the lipid layers. [14, 15, 16]

3. Lipid drug conjugates (LDC) nanoparticles: The LDC can be prepared either by salt formation with a fatty acid or by covalent linkage with ester or ethers followed by subsequent processing with aqueous surfactant e.g. Tweens using high pressure homogenization (HPH) [17, 18, 19]

4. Microsponge: Micrporous beads (10 to 25 micrometer in diameter) loaded or entrapped with the active agent having properties like inertness, improved stability, reduced irritation, miscibility with water, improved safeguard, which may respond to external stimuli had a wide variety of applications as Microsponge. Examples include antipruritics, rubefacients, antidandruff preparations, skin depigmenting agents, antiperspirant sprays etc.

Characterization of nanometerials [20]

- ✓ Particle morphological property: usually evaluated by transmission electron microscopy (TEM), scanning electron microscopy (SEM), atomic force microscopy (AFM) and dynamic light scattering (DLS).
- ✓ Particle's surface characteristics: commonly analysed by X-ray photoelectron spectroscopy (XPS), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR).
- ✓ Separation and quantification of nanoparticles with different particle size: monitored by High-performance Liquid Chromatography (HPLC) with Size Exclusion Chromatography.

Understanding of nanomaterial interaction with the environment in combination with an understanding of the route of exposure; the penetration of nanoparticles through the skin, their bio distribution, rate of excretion and toxicity are determined by the nanoparticle's characteristics (e.g., shape, size, surface charge, surface composition, coating, type of materials, and other components in the nanoparticle's formulations).

Novel cosmetic Delivery systems [21]

I. Vesicular Delivery systems

Liposomes

Niosomes

Silicone vesicles and Matrices

Multi-walled Delivery systems

II. Particulate Systems

Microparticulates

Porous polymeric systems

Nanoparticulates

III. Emulsion Delivery Systems

Microemulsions

Crystals

Multiple emulsions

Nanoemulsions

Pickering emulsions

IV. Other Delivery systems

Cyclodextrin complexes

Carbosomes

Dendrimers and hyperbranched polymers

Nano Crystals

V. Delivery Devices

Iontophoresis

Cosmetic patches

Number of factors that influence the dermal absorption of nanoparticles can be divided into three groups as location and skin conditions at the application site, physicochemical properties of the penetrating molecule, and physicochemical properties of the vehicle dispersing the penetrating molecule.

Application of nanotechnology in cosmetics

Nanosomes are applied as antiaging serum for enhanced performance designed to upgrade skin to a healthy and youthful looking stage. [22] Polyvinyl alcohol (PVA) with fatty acids (FAs) have been used to create polymeric nanoparticles, cause the absorption of benzophenone-3 (BZP), these are formulated as nanocapsule which widely used as UV filter. [23] Nanoemulsion made by oxyalkylene glycols and selected oils, protein adherent polymers with hydroxyl substituted aromatic groups helps to nail lacquers reportedly adhere well to the nails, are characterized by good gloss, exhibit good water resistance[24] & to increase the adhesiveness and durability of nail polish compositions.[25] Molecular sunscreens are incorporated in SLN, leads to synergistic UV-blocking effects. [26] Nanostructured lipid carriers act as excellent moisturizer for all types of skin. [27] Pickering emulsions in which the stabilizing particles are zinc oxide or titanium dioxide that have been coated with aluminium stearate or dimethicone and aluminium hydroxide or silicon dioxide,[28] that favours the storage of retinol inside the stratum corneum , acts as anti-aging cream. [29]

Present status & future prospects

Nanotechnology is the fastest developing area of research involved in resolving science-based solutions for innovative therapeutics and cosmetics. In future, it is going to become a big prospect for cosmetics and consumer care product manufacturers. As this area of technology is still relatively new, researchers have to look into solubility and bio-persistence of the nanometerials very carefully. The most commonly used nanopigments in cosmetics are titanium dioxide, zinc oxide and aluminium oxide. [30] Nano-aluminium oxide is used in concealers and mineral foundations because it diffuses light, giving a ‘soft focus’ effect that disguises wrinkles. Nano-titanium dioxide is used to give protection from UV rays of sun. As a larger particle, titanium dioxide is white and opaque. [30] But in nano size, titanium dioxide becomes transparent. Nanoparticles of iron oxide are used as pigments. Nanosized TiO_2 particles stay on the outer surface or stratum corneum of the skin and do not penetrate through the living skin. Production of free radicals by nanoparticles used in sunscreens and cosmetics is greater when exposed to UV light. Nano-sized titanium dioxide sometimes penetrates the skin and therefore be of prime concern for people with healthy skin. Fullerenes have been also used as nanometerials in anti-aging cosmetic products but uncertain about their potential toxicity as well as scepticism about their anti-aging claims. Some cosmetics developers create an idea about silver nanoparticles, they want to use this type of nanoparticles in toothpaste. Nowadays, Gold nanoparticles are included in facial masks, being used in beauty clinics and saloons. It is believed to work by improving the blood circulation, skin elasticity, and reducing the formation of wrinkles & they do not produce toxicity in human skin. [31-34]

Risk assessment techniques

Making of nanomaterials attractive to the cosmetics and personal care industries have to alter color, transparency, solubility and chemical reactivity [34] Currently there are few social issues about the impact of nanoparticles used extensively in sunscreens like Titanium dioxide, Zinc oxide, on environment, health and safety[2] Nanomaterials used in sunscreens, an assessment of phototoxicology is necessary to determine if nanoparticles/nanomaterials have the capacity to generate free radicals in the presence of sunlight and if the addition of antioxidants in the formulation could eliminate any free-radical damage. Recent sunscreens contain insoluble nanoparticles (colourless) of titanium dioxide (TiO2) or zinc oxide (ZnO), which reflect / disperse ultraviolet more effectively than bigger particles. The nano-sized particles are used in sunscreens as a substitute to existing chemical UV absorbers, such as p-aminobenzoic acid and benzophenones, which can cause sensitivity reactions individuals. The National Institute for Occupational Safety and Health (NIOSH) has published a report in 2005 with conclusion that little concentrations of inhaled TiO2 were an unlikely cause of cancer in humans. Although other nanoparticles like carbon nanotubes, fullerene derivatives and quantum dots may have properties that require safety assessment on case to case basis prior to human use.[35,36] Fullerenes in cosmetics will enhance human exposure through product utilization, and like other chemicals found in personal care products, can potentially be released into the environment after being rinsed "down the drain". [37] Such evaluations must use validated analytical techniques like high-performance liquid chromatography (HPLC) for fullerene detection in complex matrices like cosmetics. Satisfactory assessment of the environmental and human health impacts of nanoparticles (e.g., C60) in consumer products would be valuable information for decision- making, and could therefore help prevent public distrust. [38]

Opportunities to exploit the benefits of technologies in the cosmetic industry

- ✓ TiO2 and ZnO are widely used in cosmetic formulations. However, there is a need for an in-depth toxicity study these materials as the studies so far have brought mixed results.
- ✓ Liposomes and nanoemulsions do not disturb the integrity of the skin lipid bilayers and are not washed out while cleansing the skin. So, these formulations are believed to have a great future in the cosmetic science.
- ✓ Acceptability of microemulsions, however, would be governed by the use of safer surfactants, which do not appreciably change the permeability of membrane over repeated use.
- ✓ Encapsulation techniques and trigger-release mechanisms have been developed for the active delivery of cosmetic molecules. However, there is a need for reliable, cost effective triggers for controlled release.
- ✓ Improvements in the drug loading efficiency of lipid based nanoparticles (SLNs and NLCs) and nanocapsules are required.
- ✓ Better understanding of how lipid nanoparticles modify drug penetration into the skin, how they affect the drug penetration and how they interact with lipids of the stratum corneum is required.
- ✓ Fundamental conditions for the formation of SLNs and NLCs and the effect of surfactants used for modifications need to be studied further.
- ✓ Further in vivo studies on the effect of cosmetics that contain nanomaterials.

CONCLUSION

Nanotechnology is considered to be a new industrial revolution and also proved to be beneficial in many dermatological and cosmetic preparations. For diminishing the risk factors, formulators have to improve the legal clarities, proper labelling of the products, ensure that cosmetics products which have to be marketed are properly safe & fulfil the claims which are labelled. [30]

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