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SCOPE OF NANOTECHNOLOGY IN NUTRACEUTICALS, COSMECEUTICALS AND DENTISTRY - REVIEW

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ABSTRACT: Nanotechnology is predicted to change health care essentially. The word nano originates from the Greek word "dwarf". The idea of nanotechnology was first explained in 1959 by Richard Feynman. Nanotechnology has applications in many fields, including Medicine, Diagnostics, Drug delivery, Tissue engineering, Pharmaceuticals, Cosmeceuticals, Nutraceuticals, Dental materials, the Food industry *etc.* Nanotechnology is a multidisciplinary science that aims to design structures on a nanometric scale. Nanotechnology in drug delivery has appeared in nanoformulations with unique properties both in vivo and in vitro, particularly in targeted delivery. Nanotechnology has the potential to transform every aspect related to the food industry, food packaging, food storage, processing, pesticide, and food sensors which are some of the aspects of the food industry where prominent research is in progress utilizing the unique physicochemical properties of nanomaterials. Using these nanoparticles in the dietary supplement industry may improve supplement absorption and the bioavailability of drugs, nutraceuticals, and cosmetics.

INTRODUCTION: National Nanotechnology Initiative (NNI) is known to be the world's largest funding source for nanotechnology examination, and as indicated by them, nanotechnology can be characterized as "the understanding and control of issue at aspects between approximately 1 and 100 nanometres, where unique peculiarities empower

novel applications not feasible when working with bulk materials or even with a single atom or molecule incorporating nanoscale science, engineering and innovation, nanotechnology includes imaging, measuring, modelling and manipulating matter at this length scale".

Nanomedicine researchers have found that Therapeutic nanoparticles (NPS) can give a more compelling drug delivery system than conventional forms of drugs. The nanoparticles can be produced utilizing phospholipids, lactic acid, chitosan, dextran, polyethylene glycol (PEG), cholesterol, carbon, silica, and some metals. Among these, Nano-liposomes, produced using phospholipids,

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have drawn great interest as proficient carriers for nutrients, drugs and other bioactive agents. Nanomaterials can either be naturally occurring or be externally added. The most broadly utilized nanostructures in the food industry are engineered nanomaterials, Nanoemulsion, Nanoliposomes and nanofibers.

Role of Nanotechnology in Nutraceuticals:

Market Analysis: The global nutraceuticals market is projected to develop at a CAGR of 7.5% during the estimated period (2021 - 2026). The nutraceuticals market in India is expected to develop from \$ 4 billion in 2017 to \$ 18 billion in 2025 in the backdrop of rising demand for dietary supplements from the upper and middle class. The worldwide nutraceuticals market is expected to witness predictable development following the outbreak of COVID-19, as these include the food ingredients that give medical or health benefits to prevent infections and boost the overall immune system. The global nutraceutical market is fragmented into functional food, functional beverage, and dietary enhancement¹. The functional food segment is additionally categorized as cereal, bakery and confectionery, dairy, snacks, and other useful food varieties. Functional beverages are sub-portioned as energy drinks, sports drinks, fortified juice, dairy and dairy alternatives, and other functional beverages. Dietary enhancements are categorized as vitamins, minerals, botanicals, enzymes, fatty acids, proteins, and other dietary enhancements.

Introduction: The term nutraceutical was instituted in 1989 by Stephen L. De Felice, founder, and chairman of the Foundation of Innovative Medicine (New York), combining nutrition and pharmaceutical^{2,3}. Nutraceuticals are defined as foods, or part of foods, giving medical and health benefits such as preventing and treating diseases^{3,4}. Nutraceuticals are a combination of nutrition and pharmaceuticals which have health benefits with their actual function of giving nutrition and are subsequently used to prevent the occurrence of a disease or as its therapy. Principles of nanotechnology have been carried out by different researchers for the proficient delivery of nutraceuticals with the aim to upgrade their biological action⁵. Several formulations have been used to deliver this nutraceutical, like

nanoemulsion, micelles, nanoparticles, Nanocapsules, Nanocochleates, nanocrystals, etc²⁷. These nanoformulations are benefitted in designated delivery of encapsulated nutraceuticals with controlled delivery and better bioavailability as well as give assurance for bioactive compounds such as vitamins, antioxidants, proteins, carbohydrates and lipids with improved functionality and dependability⁶.

Whenever a multitude of bioactive and active ingredients are nanoencapsulation, they can break down and get absorbed by the common food after delivering their active ingredients. Nanomaterials reveal elite properties because of their small size and high surface/volume ratio; they have a complete application in nutraceuticals and the food sector¹. Nutraceuticals range from secluded nutrients and dietary enhancements to processed products, such as cereals and beverages⁷. It is made up of two terms Nutrition and Pharmaceuticals. Nutraceuticals are characterized as components/nutrients secluded or purified from food sources that have health benefits other than their actual function of providing nutrition and are therefore utilized to prevent the occurrence of a disease or are utilized in its treatment²⁸. They are usually sold in therapeutic structures not associated with the food sources from which are derived/isolated. The developed Nanoformulations provide targeted delivery of the encapsulated phytochemical and sustained delivery from the Nanoformulation other than improving its bioavailability and subsequently therapeutic adequacy.

Applications: The achievement of nutraceuticals can be attributed to their trait of imparting positive therapeutic benefits with a decrease in the side effects related to the utilization of pharmaceutical substances utilized in the prevention and treatment of various ailments¹². Over the years, by doing appropriate experiments, researchers globally have demonstrated beyond doubt that nutraceuticals protect against many diseases, including cardiovascular diseases, cancer, diabetes, and even neurodegenerative disorders¹³. Although the list of nutraceuticals utilized in the treatment of diseases is quite long, however throughout recent years, phytochemicals with potential health and physiological benefits such as herbal polyphenols,

to name a few curcumin, resveratrol, blueberry, rutin and carotenoids like beta-carotene present in yellow, orange, and green vegetables and fruits have drawn researchers as well as consumers not only due to their ability to prevent and treat various

diseases like cancers, cardiovascular disorders, and even surprisingly neurodegenerative disorders like Alzheimer's disease because of their inherent antioxidant property additionally because of their beneficial impacts in improving the immunity²⁹.

TABLE 1: APPLICATIONS OF NUTRACEUTICALS FORMULATED AS NANOMATERIALS

S. no.	Functional food components	Delivery system/ Experimental model/ Route	Major activities / Application	Reference
1	Hydrophobins (Hyd)- Vitamin D3	Nanoencapsulation	Hydviewed as a promising Nano vehicle of hydrophobic nutraceutical for food beverage enrichment. Hyd provide excellent protection vitamin D3 against degradation	Israeli-Lev <i>et al</i> ¹⁰
2.	Folic acid with whey protein and commercial resistant starch	Nanoencapsulation	Greater encapsulation efficiency. Improved folic acid stability. Increase bioactive stabilization	Pérez-Masiá <i>et al</i> ¹¹
3.	β-carotene, folic acid, curcumin and ergocalciferol	Protein-polysaccharide soluble nanocomplex	To increase the antioxidant activity	Hosseini <i>et al</i> ¹⁵
4.	Carotenoids	Lipid nanocarriers	Great potential for clinical applications. A new delivery system for lipophilic plant extracts	Lacatusu <i>et al</i> ¹⁶
5.	Omega-3-fatty acids and oil-soluble vitamins	Biopolymeric nanogels	Encapsulate and protect bioactive. Utilized only food- grade ingredients fabricated system improves the quality of food and beverages	Matalanis <i>et al</i> ¹⁹
6.	Curcumin	Organogel based nanoemulsion	Digestion of nanoemulsion significantly fast and complete. Oral bioavailability of curcumin increased. Can be utilized in functional foods, dietary supplements and pharmaceutical industries	Yu <i>et al</i> ²⁰
7.	α-tocopherol	Supercritical assisted nanosuspension	Increases the dissolution rate. Increases bioavailability. Increases the stability	Campardelli <i>et al</i> ²¹
8.	Clove oil and Eugenol Oil	titration–precipitation of COM and EM	Formulation in microemulsion provides a delivery system for oral administration of clove oil in homogenous, water-based and thermodynamically stable dose	Al-Okbi <i>et al</i> ²³
9.	Folic acid and calcium	Dual nutraceutical nanomaterial	To provide a high content of essential nutrients in human health	Niddi ³³

A significant issue in this field is the poor bioavailability of nutraceuticals, excreted from the body without giving any medicinal benefit¹⁷.

To increase absorption, bioavailability and controlled release of nutrients and health supplements, nanotechnology can be utilized^{8, 9}. The unique properties of nanomaterials (NM) are because of their small size, usually ranging from 1 to 100 nm¹⁴.

Based on their chemical composition, NM in nutraceutical formulations can be organic or inorganic. Organic NM can act either as the dynamic fixing – self-assembly omega-3 fatty acids – or as delivery systems of active ingredients¹⁸. Inorganic NM are the active ingredients

themselves, as in the case of nanosilver and zinc oxide-based formulations.

Role of Nanotechnology in Cosmeceuticals:

Market Analysis: A report, “Cosmeceuticals market to 2018,” forecasted that the worldwide cosmeceuticals market would reach \$ 42.4 billion by 2018. The cosmeceuticals Market size was esteemed at USD 41.5 Billion in 2020 and is projected to arrive at USD 80.67 Billion by 2028, growing at a CAGR of 8.64 % from 2021 to 2028.

Introduction: Cosmeceuticals are defined as cosmetic products that might have medicinal or drug-like benefits. It may be inferred naturally or is also synthesized with chemicals²². The term Cosmeceuticals was created in the 1990s from

Cosmetic and Pharmaceuticals. Cosmeceuticals are presently an integral part of aesthetic medicine and the development of cosmeceuticals are expanding day by day²⁴. The unique category of the product gives patients access to cosmetics containing beneficially active ingredients that can be utilized to improve their skin appearance²⁵.

Applications: Nano cosmeceuticals utilized for skin, hair, nail, and lip care, for conditions like wrinkles, photoaging, hyperpigmentation, dandruff, and hair damage, have become widespread use²⁶. Novel Nano carriers like liposomes, niosomes, Nanoemulsions, microemulsions, solid lipid nanoparticles, nanostructured lipid carrier, gold & silver nanoparticles, cubosomes, hydrogels and Nano spheres have replaced the usage of conventional delivery systems. These novel nanocarriers have the benefits of upgraded skin penetration, controlled and sustained drug release, higher stability, site-specific targeting, and high entrapment efficiency³³.

Role of Nanotechnology in Dentistry:

Market Analysis: The worldwide Nano-Dentistry market size will be USD million, and it is expected to arrive at USD million by the end of 2027, with a CAGR of % during 2021-2027.

Introduction: Because of the developing interest in the future of the dental application of nanotechnology, a new field called nano dentistry is emerging. The advancement of Nanodentistry permits almost perfect oral health by the utilization of nanomaterials and biotechnologies including tissue engineering and nanorobots³². Nanodentistry incorporates Nanorobotics, Nanodiagnostics, and Nanomaterials. Nanotechnology has revolutionized restorative dentistry by providing nanofillers. These filler particles are very minute; higher proportions can be accomplished and result in indistinctive physical, mechanical and optical properties.

Applications: The new treatment opportunities in dentistry include local anaesthesia, dentition renaturalization, permanent cure of hypersensitivity, a complete orthodontic realignment during a single visit, covalently bonded diamondized enamel and continuous oral health maintenance with the help of mechanical dentifrobots (nanorobotics dentifrice) that

annihilate caries-causing micro-organisms and even repair imperfections on the teeth where decay has set in. Application of nanotechnology in diagnosis and treatment includes diagnosis and treatment of oral cancer, tissue engineering and dentistry, bio-nano surface technology and dental implants, Bone replacement materials, Nanoanaesthesia, Nanosolutions.

Impression materials, Nano needles, dentifrobots, Nanocomposites-nanocomposites artificial teeth, nanotechnology for preventing dental caries, digital dental imaging, significant tooth repair/Nanotissue engineering. Implantable materials can be applied in different fields like tissue healing and substitution, Coatings for implants, Tissue regeneration scaffolds, Implant materials, Osseous repair, Bioresorbable materials, Smart materials, Diagnostic and therapeutic devices, Sensory aids Cochlear and retinal implants³¹.

According to recent reports, oral hygiene products such as toothpaste and mouthwash solutions were additionally Nano-modified. Nano-calcium fluoride, for instance, was added to mouthwash products to reduce caries activity, decrease dentine permeability, and increase labile fluoride concentration in oral fluid³⁴.

Toothpaste containing calcium carbonate nanoparticles and 3% Nano-sized sodium trimetaphosphate has been accounted to promote remineralization of early carious lesions compared to conventional toothpaste with no Nano-additives³⁵.

Metallic nanoparticles such as gold, silver, platinum, and palladium are commonly consolidated in Nano biosensor transduction/bio reception systems as they are able to rapidly respond to most biological molecules without influencing their action³⁶. Applications of nanotechnology in Prosthodontics incorporates the consolidation of 0.4% TiO₂ nanoparticles into a 3D printed poly-methyl methacrylate (PMMA) denture base was examined in 2017, in an attempt to improve its antibacterial attributes and mechanical properties³⁷. Nanotechnology applications in endodontics incorporate the joining of bio-ceramic nanoparticles such as bioglass, zirconia and glass ceramics in endodontic sealers

³⁰. In periodontics, implantology and regenerative dentistry researchers were able to create a novel drug delivery system for the treatment of

periodontal disease, through triclosan or tetracycline loaded nanoparticles.

TABLE 2: COMMERCIAL NANOPARTICLES USED IN DENTISTRY

S. no.	Discipline	Classification	Material	Nanoparticle
1.	Prosthodontics	Denture teeth	Nano-hybrid composite	Silicon oxide
2.	Conservative	Restorations	Nano-Resin modified GIC	Zirconia/silica nanofillers & nanoclusters
3.	Conservative	Restorations	Nano-Composite Resins	Nanosilica SO ₂ spherical nanofillers
4.	Conservative	Cavity Disinfectant	Mineral solution	Spherical silver nanoparticles (48 nm)
5.	Endodontics	Sealer	Silicon based	Nano-silver
6.	Periodontics	Grafts	Bone grafts	Nanocrystalline hydroxyapatite
7.	Implantology	Nano-implant coating	-	Nano-hydroxyapatite (around 50% of total surface area)

CONCLUSION: Overall, this review indicates that nanotechnology has great potential for delivering nutraceuticals, cosmeceuticals, and dentistry; in light of the comprehensive health problems, its utilization for effective disease prevention and health promotion is necessary it is to be anticipated. Even though nanotechnology has promising approaches additional innovative research is needed to address the cost effective and long term safety of the nanomaterials.

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