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Nano Nutraceuticals: Revolutionizing the Future of Health Supplements

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A promising new avenue for improving health and wellness is presented by the combination of nutraceuticals with nanotechnology. The application of nanotechnology to nutraceuticals is examined in this abstract, with particular attention on how it might transform bioactive substances' bioavailability, efficacy, and delivery methods. With nanotechnology's exact manipulation at the nanoscale, new delivery vehicles, including liposomes, nanoparticles, and nanoemulsions, can be designed. These platforms solve problems with traditional formulations by enhancing nutraceutical chemicals' solubility and stability. Furthermore, nano-based carriers make targeted delivery easier, which guarantees the body's best possible absorption and dispersion. Moreover, functionalization possibilities provided by nanotechnology enable the addition of bioresponsive components for site-specific targeting and triggered release. Furthermore, real-time monitoring of physiological parameters made possible by the integration of nanosensors allows for customized interventions and accurate dosing schedules.

Keywords: Bioactive agents; Drug delivery; Functional foods; Nanotechnology; Nutraceuticals.

The combination of nanotechnology and nutraceuticals has become a cutting-edge field with revolutionary promise in the rapidly changing fields of healthcare and well-being. The health-promoting qualities of nutraceuticals, which are made up of bioactive compounds derived from natural components, have long been acknowledged. However, obstacles including poor transport efficiency, stability problems, and low bioavailability have prevented them from having their full therapeutic potential. The field of nanotechnology, which works with matter at the nanoscale, offers exact answers to these enduring problems.

This introduction lays the groundwork for an exploration of the emerging topic of neutraceutical nanotechnology, where combining these two fields has the potential to alter perceptions of health and wellness completely. Nutraceuticals can be tailored for optimal distribution, improved efficacy, and targeted action within the body by utilizing the unique qualities of nanomaterial, such

as increased surface area, adjustable reactivity, and enhanced transport capabilities.

This investigation will explore the complexities of nanoencapsulation, nanoemulsions, and nanoparticle-based delivery systems three important tactics advancing innovation in the field of nutraceutical nanotechnology as we go deeper into this area. We will also explore how personalized nutrition solutions could be made possible by nanotechnology, which could allow interventions to be customized to each person's physiological demands and preferences.

Neutraceuticals

"Nutraceuticals" and "functional foods" are phrases that are commonly used interchangeably in media and publications. The term "nutraceutical," is the combination of the terms "nutrition" and "pharmaceutical," and was coined by Stephen DeFelice, M.D., the founder of the Foundation for Innovation in Medicine in Cranford, New Jersey.

There are many different products included in it, including functional foods, isolated nutrients, medicinal foods, fortified foods, and dietary supplements. Consequently, dietary ingredients or whole foods having health advantages, such as illness prevention and treatment, would constitute a more realistic description of nutraceuticals. Previously, the US Food and Drug Administration (USFDA) has listed specific foods that are utilized for the.[1]

Types of nutraceuticals and example

There are various types of nutraceuticals used in day-to-day life of human beings following are some of the examples of these nutraceuticals shown in Figure 1.

Liposomes, nanoparticles, nanosuspensions, and polymeric micelles are examples of drug-delivery systems that use nanotechnology to improve solubility of drug, its therapeutic efficacy, permeability, stability, and oral bioavailability. Nutraceuticals particles have trouble reaching to their target site for many reasons, including poor gastrointestinal tract (GIT) absorption brought on by problems with the solubility of active medicinal substances, like vitamin and calcium supplements. Therapeutic activity may be impacted by interactions between nutraceutical products and chemicals, medications, and other nutraceuticals. The problems with solubility and absorption may be solved using nanotechnology. A molecule's surface area increases with size decrease, enhancing the intended biological process. Converting a nutraceutical molecule into a nanocarrier is one method of overcoming the barriers. The pharmacological approach uses nano-delivery technologies extensively.[2] Some examples of phytoconstituents used as nutraceuticals are shown in Figure 2

Classification of nutraceuticals

The natural food sources that are utilised to make nutraceuticals fall into the following categories shown in Figure 3

Problems in nutraceutical delivery

The primary causes of a nutraceutical's poor oral delivery are the target capacity and oral absorption of the constituent. The limited serum dispersion, apparent rapid metabolism, and short half-life of nutraceuticals may all contribute to their poor bioavailability.[3]

Nanotechnology in nutraceuticals

Numerous dangerous diseases, such as cancer, hypertension, osteoporosis, diabetes, obesity, infectious diseases, hyperlipidaemia, and pain and inflammation, are becoming more common as the world's population grows. Nutraceuticals have a low bioavailability, meaning they are routinely eliminated from the body without providing any therapeutic benefit. This is the main cause for concern in this subject. Nanotechnology can be used to increase the oral bioavailability, permeability, and therefore the bioavailability of nutritional and health supplements.[4],[5] These are shown in Table 1. Nanomaterials have extraordinary qualities because of their tiny size. a high surface area to volume ratio, and increased efficiency as a result of increased uptake by endocytosis and additional biological transport processes.[3,6]

The chemical composition of nanomaterials can be used to further classify them into organic and inorganic types. These organic or inorganic nanoparticles can function as delivery systems or the therapeutic agents (self-assembling omega-3 fatty acids, Nanosilver, and zinc-oxide-based formulations, among others).

Various types of nanocarriers are used for nutraceutical delivery

Nanocarriers are innovative delivery

systems used to enhance the stability, bioavailability, and controlled release of nutraceuticals. These tiny carriers can protect sensitive bioactive compounds and improve their absorption in the body. Various types of nanocarriers used for nutraceutical delivery are shown in Table 2.

Targeted delivery system

Targeted nano-delivery systems can be created by physically or chemically bonding tiny molecules, antibodies, proteins, peptides, and nucleic acid aptamers to the delivery vehicle's surface. Adding folic acid on the surface of nanoparticles is one of the best examples of a targeted delivery method since it exhibits increased efficiency in a variety of cancer types and greater affinity towards folate receptors.[12, 13] Similar to this, many additional tiny molecules, short peptides, antibodies, and polysaccharides have been created and used for certain functions.

Impact on nutritional values and feed quality

Use of micelle particles to construct spheres (~30 nm) encasing nutraceuticals such as beta-carotene, CoQ10, DHA/EPA, and other chemicals is known as nano-sized self-assembled liquid structures (NSLS). For better bioavailability in meals and feeds, micellar regulation via thermodynamics improves the solubility of non-polar compounds (fats, antioxidants). Hydrophilic inside and hydrophobic outside surfaces of lipid-based micelles facilitate the transportation of ingested substances into the bloodstream, hence increasing bioavailability even more. To spread fat-soluble nutrients in water-based beverages, liposomes—another archetype—encapsulate lipids and water-soluble components. Liposomes are scalable, ranging in size from 10 to 500 nm, and they provide specialized solutions for a range of situations while maintaining stability.

Adsorbed biological molecules exhibit altered behavior due to the presence of nanoparticles, which impact their stability, structure, and function. Interestingly, enzymes attached to nanoparticles, such as trypsin and peroxidase, remain active for extended periods from hours to weeks. Product functioning and quality are improved by this nanoscale manipulation.[14,17]

Applications of neutraceuticals in feed processing

With its cutting-edge approaches to packaging and nutrition enhancement, nanotechnology has completely transformed the food and feed processing industries. Nutrient-carrying nano capsules that improve absorption without changing flavor or appearance represent a noteworthy development. 50 nm coiled nanoparticles called nano-cochleates effectively transport nutrients to cells, including vitamins and omega fatty acids.[18]

Nanotechnology in the processing of food and dairy product

The food and dairy sectors use nanotechnology primarily in two areas: food additives ("Nano Inside") and packaging ("Nano Outside"). Food additives include functional components such as vitamins, antioxidants, and colorants in different molecular forms and states, as well as nano dispersions and capsules.[19]

Nano-processed food

Foods prepared with nanotechnology are widely accessible, but frequently labeled with little information. Diverse regulatory control exists, with few requirements for public knowledge, safety, and labeling. Big companies that make significant investments in nanofood R&D include Unilever and Nestle. Collaboration is key to future breakthroughs, as demonstrated by Kraft's "Nanotek Research Consortium".[20]

'Fortification' of food with nanotechnology

Food "fortification," which improves nutritional content, flavor, and appearance, is made possible by nanotechnology. For example, nanoparticles can change the amount of fat and sugar in processed foods, which may have positive effects on health. Potential future uses could involve marketing snacks as health-promoting because they contain "medically beneficial" nano-capsules or modifying how fat and sugar are absorbed using nutraceuticals and nanotechnology.

Nanotechnology in food Systems:

The potential of nanotechnology in food systems was highlighted at the First International Food Nanotechnology Conference in Atlanta in 2006:

1. Health promotion: Delivering bioactive compounds.
2. Improved functionality: Enhancing flavors, and textures.
3. Innovative packaging: Microbial-repellent materials.

4. Nanosensors: Monitoring food safety, and shelf life.

Nanosized and nanostructured materials

Nanoencapsulation

Taste encapsulation made possible by nanotechnology improves flavor release, retention, and harmony in cooking. While delivering food additives, nanocarriers preserve the structure of the ingredients. Originally used in pharmaceuticals, nanoencapsulation increases the solubility of antioxidants, vitamins, and omega oils while protecting them from airborne contaminants such as heat, light, and oxygen. It is possible to mask unpleasant tastes, colours, and smells. Nanosized lipid-containing water-in-oil-in-water emulsions enhance the durability and spread ability of food.

Main types of Nanoencapsulation System

Lipid-Based

- Liposomes
- Lipid Bilayer Structure
- The high energy required for dispersion
- Cochleates
- Multilayered Spiral Structure
- Fuses with Cell Membrane for Targeted Delivery

Biopolymer Based

- Proteins
- Milk or Whey proteins
- Casein Micelles (CM)
- Self-assembled nano capsules
- Natural Carriers for Nutrients and Minerals
- Stabilization and encapsulation of Hydrophobic nutraceutical materials.

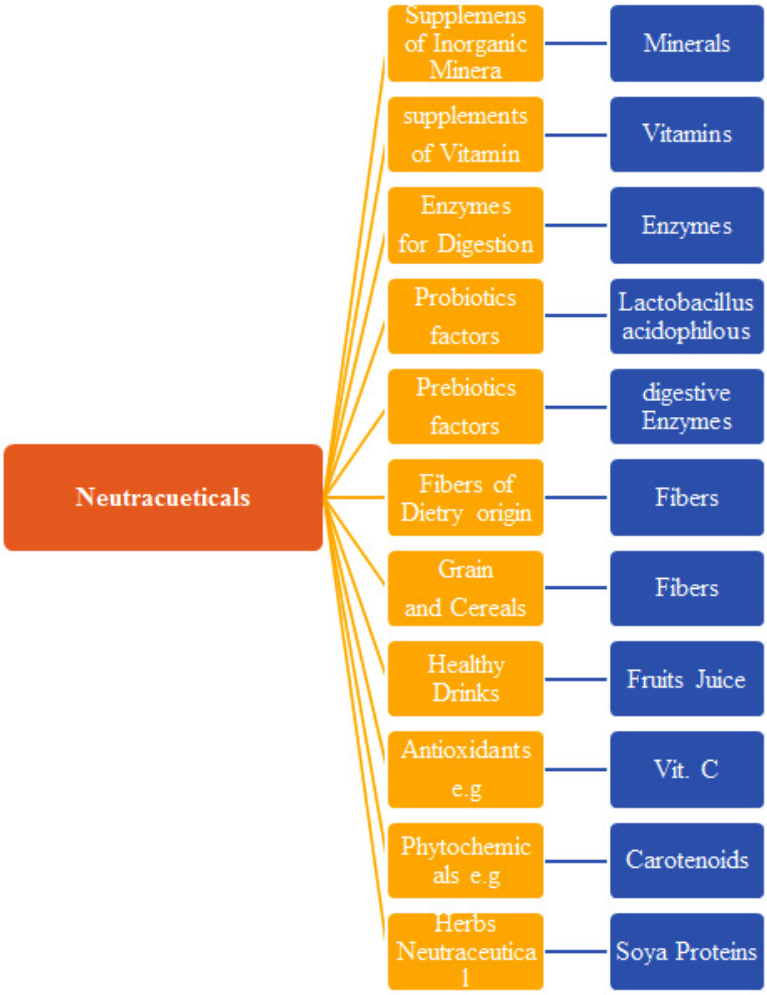

Fig. 1. Types of nutraceuticals

Emulsion type systems

Using phases with different polarity, emulsion-type systems make it easier for hydrophobic food ingredients to be transported in aqueous phase emulsions. The two primary types of emulsions are the oil-in-water (O/W) and the water-in-oil (W/O), along with corresponding nano-emulsions. O/W emulsions are frequently found in milk, cream, dressings, and beverages, whereas the W/O emulsions are found in butter and certain spreads.

Conventional emulsions look opaque and milky, with droplet widths typically ranging from 100 nm to 100 ìm. Conversely, microemulsions are optically transparent, have negligible interfacial tension, smaller droplet sizes (between 1 and 20 nm), and thermodynamic stability. In addition to improving the absorption of essential oils, nano emulsions aid in the solubilization of phytochemicals such as curcumin. Their small droplet size and optical clarity make them promising in the beverage industry; vitamin D-delivering nano emulsions based on cinnamon oil are one example.

Nanoencapsulation of antimicrobial agents

Liposomes are lipid-based spherical particles with an aqueous core that are useful for the effective nanoencapsulation of antimicrobial drugs like lysozyme and nisin. For proteins in particular, these structures offer a protective microenvironment that keeps hydrophilic antimicrobials stable even in the face of alterations in the surrounding aqueous phase. Liposome-encapsulated nisin maintained its antibacterial activity when exposed to typical food processing stressors, particularly in conditions with moderate heating and variable pH levels.

Nanoemulsions require less surfactant than microemulsions for the same amount of emulsion formation. Selecting the right surfactant is crucial; small-molecule surfactants, including monoglycerides and sucrose esters, function effectively because they cover recently formed surfaces rapidly. Production of nanoemulsions depends on this quick action. The appearance of an emulsion is greatly affected by droplet size; droplets with diameters less than 90–100 nm is transparent and suitable for use in clear beverage applications.

Nanoencapsulation of vitamins

Vitamin bioavailability is increased through nanoencapsulation, which protects vitamins within stable capsules against deterioration and undesirable odors are shown in Table 3. These capsules optimize cellular absorption and targeting

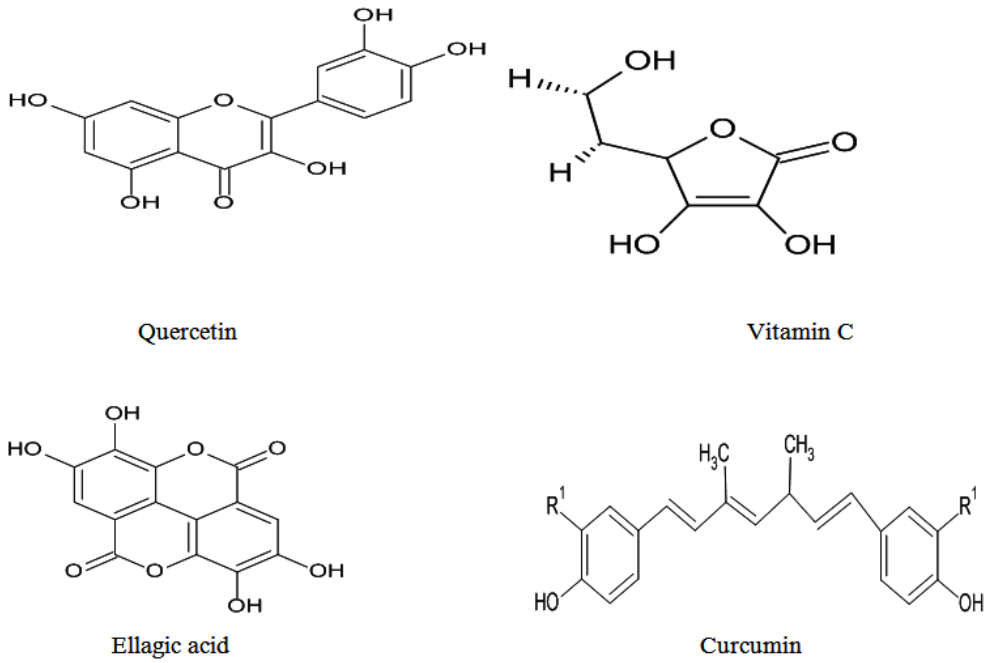

Fig. 2. Phytoconstituents as a Nutraceutical

by facilitating regulated release. Through increased colloid stability, they overcome absorption constraints and structural alterations to extend shelf life and provide improved health benefits.

Vit. D nanoemulsions that were prepared with Tween 80 and rapidly stirred produced tiny droplet sizes (less than 200 nm) that developed steadily over a month. Thermal stability was improved by the addition of sodium dodecyl sulfate. Vitamin E-loaded nanoemulsions containing either propylene glycol or ethanol demonstrated physical stability in a range of environments, maintaining vitamin content, particularly in low light. After orange juice was pasteurized, liposomal compositions improved its microbiological stability and antioxidant activity.

Applications of nanotechnology in the food packaging

Food Packaging is revolutionized by nanotechnology through the integration of bioactive ingredients, time indicators, and scent release systems through micro- and nanoencapsulation. These packaging materials' antibacterial, antioxidant, and insect-repellent

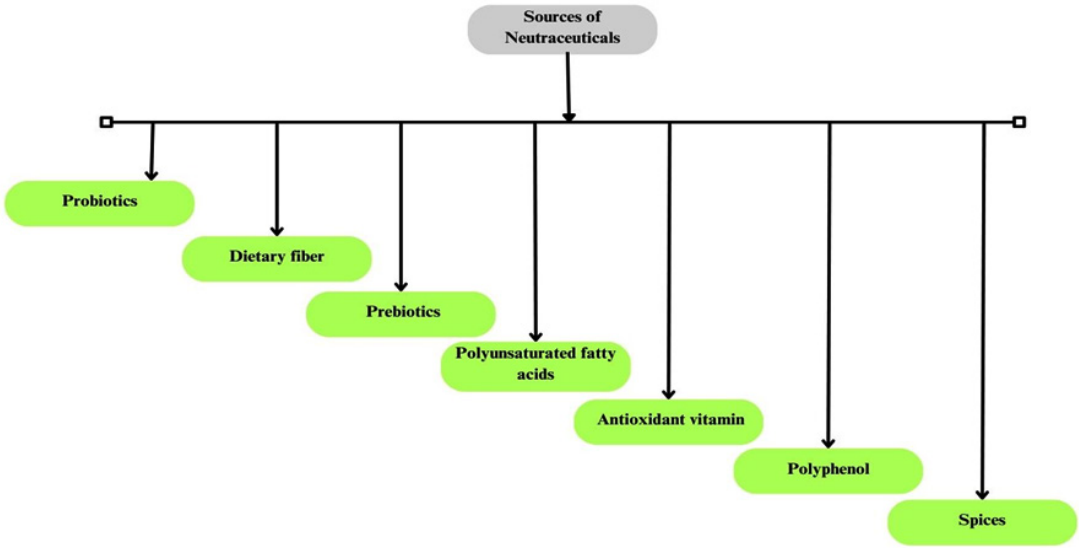

Fig. 3. Sources of nutraceuticals

Table 1. The Role of nanotechnology in the nutraceuticals industry

Nutraceutical Product	Application	Significance
Nutritional enzymes	Enzyme immobilisation of carriers Purification and separation of proteins	unique covering that kills the infection only.[3]
Nutritional additives	Anti-caking agents, nanoparticles, and nanocapsules	enhanced nutritional bioavailability and absorption as well as the elimination of contaminants and pathogens from food by selective binding. [3]
Nutritional supplements	Nanoencapsulation and nano-sensors Lipid nanoparticles in solid form	Enhanced storage, enhanced stability, and defence against deterioration. [3]
Nutritional Novel food	dietary supplements and herbal remedies	Has various health benefits. [3]
Nanoparticles used in packing of food	antimicrobial and antifungal coating for surfaces	detected compounds of foodborne pathogens. [3]

qualities improve food safety. Beyond nano silver, titanium dioxide, calcium, magnesium oxide, and zinc oxide nanoparticles provide more affordable antibacterial options. Silver has been used historically to preserve food since the time of ancient civilizations. It is also a common ingredient in space shuttle and space station water sterilization due to its broad-spectrum antibacterial activity. Although measuring nanoparticles in food and biological matrices can be difficult, there is still hope for these particles as disinfectants in a variety of applications.[1]

Nanotechnological advances for nutraceutical delivery

In addition to their true nutritional worth, super-nutrients known as nutraceuticals are isolated and purified from various types of foods including the fruits, vegetables, legumes, spices, and so on that generally improve health and are used to treat a variety of conditions and illnesses. Their origin, medicinal properties, and chemical makeup are the main classifications. Previous research also indicates that nutraceuticals have a lengthy history of health benefits; but, because of their poor physiochemical qualities, or low bioavailability, and the full potential of these substances, including curcumin, resveratrol, quercetin, and carotenoids, have not yet fully realized. Nutraceuticals and nanotechnology-based drug-delivery systems (liposomes, nanospheres, nanoemulsions, micelles, and nanocrystals) offer a novel approach to improving the efficacy and oral bioavailability of pharmaceuticals while removing additional obstacles. Developed nanoformulations not only enhance the physicochemical characteristics and therapeutic efficiency of nutraceuticals but also offer a targete-based distribution. This chapter will provide a synopsis of the entire medicinal plant.

Table 2. Various nanocarriers used for nutraceuticals

Nanocarriers	Description
Polymeric Micelles	Micelles have a core-shell structure where the hydrophobic core contains and protects the nutraceutical, while the hydrophilic head stabilizes it in an aqueous medium, enhancing water solubility. Effective for CNS disorder treatment.[7]
Nanoparticles	Prepared using hydrophilic cosolvent, hydrophobic polymer, and water. Utilizes various polymers like albumin, chitosan, heparin, etc., and synthetic ones such as PLA, PGA, PLGA, PEG, and PGA. Example: curcumin polymeric nanoparticles.[8]
Metal Nanoparticles	Includes zinc, titanium oxide, iron, and silver, exhibiting high selectivity, catalytic activity, biocompatibility, and large surface area. Utilized for nutraceuticals like cayenne pepper, ginger, and garlic. Example: spherical silver nanoparticles.[9]
Hybrid Nanoparticles	Combinations of lipid and polymer/organic or inorganic materials. Exhibit erosion and hydrolytic degradation upon contact with water. Have core layers shielded by multiple shell layers. Example: curcumin gold hybrid nanoparticles.[10,11]

Table 3. Oil and water-soluble vitamin nanoencapsulation[21]

Vitamins	System for Encapsulation
Vitamins that are Soluble in Oil	
D	Nanoemulsion
D3	Protein nanoparticle
D2	Casein micelle
D2	Solid lipid nanoparticle
E acetate	Nanoemulsion
E acetate	Polysaccharide nanoparticle
E	Liposome
Lycopene, carotene, Lutein	Chitosan
Water soluble vitamins	(Chitosan coated Liposome)
B9	Nano emulsion, double emulsions
B2	Double emulsion
C	Liposome
B12	Small unilamellar vesicle

Table 4. Application of Nanotechnology for Delivery of Nutraceuticals

Nano-based delivery System	Nutraceuticals	Remarks
Anthocyanins Solid Lipid Nanoparticles	span 85, egg, lecithin, Palmitic acid.	Stability Increases.[44]
Nanoparticles of Bromelain	Katira gum	anti-inflammatory activity Increased. [44]
Nanohydrogels of Caffeine	Lactoferrin-glyco-macro peptide	Increase skin permeation.[44]
Capsaicin Polymeric micelles	PVP K30, sodium Cholate, and Phospholipid.	Prolongation of plasma circulation and oral bioavailability increase by 99 %.[44]
Curcumin nano hydrogels and nanoparticles	Polyethylene glycol 400 and Chitosan, Hydrolyzed tetramethyl orthosilicate	Enhanced antimicrobial and healing activity. [44]
Extract of Green tea and NLC	Tween 80 Cetyl palmitate, oleic acid	Could perhaps eliminate hesperidin's poor solubility and hide its harsh aftertaste. [44]
Resveratrol Solid Lipid Nanoparticles	Polysorbate 60, miglyol-812, Cetyl palmitate.	Verified for intestinal permeability, stabilisation, and protection against trans-resveratrol. [44]
Curcumin nano emulsion	Tween 20	Regulated rate of lipid breakdown and adsorption of free fatty acids. [44]
Caffeine nanoparticle	PLGA	Notably higher tyrosine hydroxylase expression, fibre expansion, and dopaminergic neuron endurance. [44]
Caffeine Solid Lipid Nanoparticles	Softisan, Pluronic F68.	Increase skin permeation.[44]
Apigenin nanoparticles	PLGA	Potential remedies for preventing skin cancer. [44]
Apigenin nanoparticles	Mesoporous silica	Increase solubility and bioavailability . [44]
Coenzyme Q10 liposome and SLN	Compritol® 888 ATO and Lipoid S100	Enhanced topical delivery. [44]

Supplements Impacting Absorption and Intestine

It is indisputable that a healthy gut, proper absorption of nutrients, and avoidance of malnutrition depend on having an adequate composition of the "good" intestinal microflora. The intestinal microflora's composition can be altered by numerous illnesses and their treatments, which can lead to various early intestinal issues. One way to prevent these issues is to use alternative goods. Foods include chemicals called prebiotics that promote the growth or activity of beneficial bacteria. Probiotics are live bacteria, mostly belonging to the Lactobacillus and Bifidobacterium genera, that are meant to enhance or replenish the gut flora, providing health advantages. Food components or DISs that synergistically combine probiotics and prebiotics are referred to as symbiotic.[1, 21] Probiotics promote intestinal angiogenesis and control the storage of fat.[22] Prebiotics are dietary elements that are essential for the growth of intestinal microbiota and may impact intestinal health. Examples of these include inulin.[23]

Supplemental anticancer agents

Nutraceuticals such as soybeans, garlic, ginger, green tea, propolis, honey, RES, Q, EGCG, and so on may have chemo-preventive benefits. They contain the ability to cause cancer cells to undergo apoptosis. These particular foods can be utilized as supportive therapy while regular anticancer chemotherapy is being used to treat the tumor or as chemoprevention.[23,27]The production of pro-inflammatory cytokines TNF and MCP1, the release of reactive oxygen species (ROS) and ROS from human neutrophils and murine macrophages, and the proliferation of tumor cells in 4T1 breast cancer cells and FaDu head and neck squamous carcinoma cells in vitro cultures can all be effectively blocked by a

nano nutraceutical formulation of 3 PUFAs (fish oil). Docosahexaenoic acid (DHA)-containing liposomes may be used to administer fish oil fatty acids intravenously, which may be advantageous for the treatment of cancer and inflammatory diseases.[27] DHA (-3 PUFA), a component of fish oil, has been shown to inhibit cell proliferation, cause apoptosis in human breast cancer cell lines, and prevent rat mammary carcinogenesis.[28]

Dietary Supplements for Mental and Psychomotor Growth

When rats inebriated with colchicine were given fermented soybean nano nutraceuticals, AChE activity increased (42%), GSH decreased (42%), SOD decreased (43%), and catalase decreased (41%). Lipid peroxidation decreased (28%) and protein carbonyl contents decreased (30%). These findings suggest that the nano nutraceuticals may have neuroprotective properties. Additionally, an in-silico study demonstrated a significant inhibition activity of BACE-1 and amyloid-B. The nano nutraceuticals under review exhibit significant antioxidant activity, which leads one to suppose that they may also have a positive effect on cognitive impairments associated with Alzheimer's disease.[29]

Supplements for the Prophylactic Metabolic Syndrome

Sodium alginates can be used to treat GI tract problems as well as the lowering of metabolic syndrome components such as dyslipidemia, obesity, type 2 diabetes, hypertension, and non-alcoholic fatty liver disease. In addition, they may be used to treat gastric reflux illness in conjunction with antacid alginates, shielding transplanted cells from the host's immune responses. Alginates also reduce glucose and fatty acid absorption, boost weight loss in patients under calorie restriction, and induce satiety, which reduces food intake. Alginates have also been shown to lower blood pressure in rat models of hypertension.[30]

Supplements for the Management of Osteoporosis

Numerous supplements that prevent or mitigate osteoporosis's consequences are available in pharmacies. Calcium (Ca) has been shown to have an impact on osteoporosis, even though typical formulations of Ca only have a 10-15% bioavailability.[31,34] Recently, several scientific groups have investigated the use of nano-Ca for Ca supplementation. Nano-Ca can be obtained as solid peroral DISs or as nano-Ca from fortified milk. Ovariectomyctomized (OVX) rats were used in in vivo tests, which demonstrated notably greater absorption (up to 89%) and overall bioavailability (up to 42%) of formulations containing nano-CaCO3, citrate, or naturally linked oyster shells. Therefore, administering nanosized calcium has been shown through in vivo studies to increase the calcium and even phosphorus content of bones.[35,38] Oral administration of calcium hydroxyapatite microcrystals has the potential to prevent osteoporosis and speed up the healing and repair of fractures.[38]

Supplements to Prevent Iron Deficiency

Iron deficiency anemia, the most common nutritional disease in the world, has an impact on both health and the economy. The use of nanoformulations of iron was suggested as a solution to these problems in food and feed since they have improved bioavailability, good product stability, few adverse effects, and don't alter the flavor or color of the fortified foods.[39] Furthermore, studies conducted in vivo and in vitro have demonstrated that iron NPs are harmless.[40] The iron oxide nanocore of the well-absorbed protein ferritin.[41] is surrounded by a protein shell. More recently, Powell and associates.[42] Generated tartrate-modified, nano-disperse ferrihydrite with an expanded or strained lattice structure (approximately 2.7 Å for the major Bragg peak against 2.6 Å for synthetic ferrihydrite) and a small primary particle size. Because GI delivery was independent of luminal Fe (III) reduction, this ferrihydrite was able to efficiently supply soluble Fe (III) through GI transport in murine models without producing free radicals.

Application of nanotechnology for nutraceutical delivery

Nanotechnology has emerged as a transformative approach in the delivery of nutraceuticals, addressing challenges like poor bioavailability, instability, and rapid degradation. By using nanoscale carriers, bioactive compounds from foods or plants can be better protected, delivered efficiently, and released in a controlled manner. Some of them are shown in Table 4.

Regulations of nanotechnology and nanoproducts

Taste encapsulation, improved flavor

release, retention, and culinary harmony are made possible by nanotechnology. While delivering food additives, nanocarriers preserve the structure of the ingredients. Nanoencapsulation, which was first used in pharmaceuticals, increases the solubility of vitamins, omega oils, and antioxidants while protecting them from environmental toxins such as heat, light, and oxygen. Odors, tastes, and undesirable colors can be disguised.

Nanosized lipid-containing water-in-oil-in-water emulsions improve the durability and spreadability of food. This innovation increases food products' shelf life while enhancing flavor and nutrient retention in nanoscience and nanotechnology.[21,22]

Future scope

New and creative uses for nutraceuticals have been made possible by recent developments in nanoscience and nanotechnology. Nanotechnology is still a relatively recent use in food-based goods, nevertheless. Numerous well-known food companies, including Hershey, Unilever, Kraft, Nestle, Heinz, and GlaxoSmithKline, are actively racing to commercialize nanotechnology as a novel technique for nutraceuticals.[43] Despite the slower rate of development of nano-based nutraceuticals, there is still much promise for the future in the form of newer delivery platforms, innovative materials for packaging that safeguard nutraceuticals, creative processing methods, and state-of-the-art analytical tools for food quality. main goal is to break through the financial barrier to incorporate nanotechnology into food items. As newer technologies are used, fresh problems can also be expected. Furthermore, to counteract the toxicity linked to nanotechnology, considerable modifications to food-based rules are needed.

CONCLUSION

Nutraceutical nanotechnology has the potential to completely transform healthcare by increasing drug delivery, increasing bioavailability, and precisely targeting individual cells or tissues. Nutraceutical chemicals can be encapsulated thanks to nanotechnology, which shields them from digestive system breakdown and improves bloodstream absorption. As a result, the nutraceuticals' bioavailability and effectiveness are enhanced. Nutraceuticals can be precisely delivered to the site of action by using nanocarriers that are engineered to target particular cells or tissues. This improves treatment results and lessens systemic negative effects. Using nanotechnology makes it easier to combine several nutraceuticals or nutraceuticals with traditional medications in one delivery device. Increased patient compliance and better therapeutic outcomes may result from this synergistic strategy. Nutraceuticals' stability and safety profile are enhanced by nanoencapsulation, which shields them against oxidation, degradation, and interactions with other substances. By combining nanotechnology with nutraceuticals, diagnostic instruments and imaging agents can be developed that facilitate early disease identification and treatment response monitoring. To fully utilize nutraceutical nanotechnology and convert it into observable advantages for the health and well-being of people everywhere, cooperation between academic institutions, businesses, regulatory bodies, and healthcare practitioners is necessary.

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This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials

Author Contributions

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Conceptualization, Methodology, Writing – Original Draft; S.G., (Sharayu R Gajewar) D.G (Divya G Gavhane): Data Collection, Analysis, Writing – Review & Editing; P.D. (Pratik P Disale) U.M (Ujwala S Mali): Visualization, Supervision, Project Administration; P.J. (Priyanka R Jogi): Supervision.

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