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Innovations in Nanoscience for Food Security and Sustainability

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Abstract: Nanotechnology has enabled the system of developing items with length smaller than a hundred nanometers, defined as nanomaterial. these materials regularly showcase homes completely unique from their bulk counterpart. it has been studied that floor atoms of the nanoparticles are responsible for such homes. Their bodily-chemical homes of those atoms in turn are particularly depending on their morphology that can be tuned by using synthesis strategies. therefore, to comprise nanoparticles in a huge range of technological elements, like photovoltaic, sensor, digital devices, etc., numerous synthesis procedures of nanomaterials have developed through the years. nowadays, it's been found that the nanomaterials additionally have potential in numerous sectors of meals science inclusive of nano sensor, packaging substances, encapsulated food additives, and many others. Nanomaterials made from polymers, liposomes, and so on., are utilized in those regions due to their solubility, bioavailability, controlled launch, etc. in this chapter, we have mentioned antibacterial pastime of the nanomaterials in conjunction with antibacterial mechanism, consisting of oxygen species, membrane harm, etc., in the area of food technological know-how. in addition, impact of nanotechnology in meals technology has also been discussed from the perspective of meals upkeep. Nanomaterials and associated generation are very much appropriate for food packaging as they offer stronger barrier, mechanical and warmth resistivity alongside clean biodegradability.

Keywords: Component, Nanotechnology, Biotechnology, Agriculture, Nanobiotechnology

I. INTRODUCTION

The word “nano” comes from the Greek for “dwarf”. A nanometer is a thousandth of a thousandth of a thousandth of a meter (10-9 m). One nanometer is about 60,000 times smaller than a human hair in diameter or the size of a virus, a typical sheet of paper is about 100,000 nm thick, a red blood cell is about 2,000 to 5,000 nm in size, and the diameter of DNA is in the range of 2.5 nm. Therefore, nanotechnology deals with matter that ranges from one-half the diameter of DNA up to 1/20 the size of a red blood cell.1 Further, it is interesting to note that nanomaterials are so small, even bacteria would need a microscope to see them.2 Nanoparticles are generally accepted as those with a particle size below 100 nanometers where unique phenomena enable novel applications and benefits. Nanomaterials on which most of the research has been carried out are normally powders composed of nanoparticles which exhibit properties that are different from powders of the same chemical composition, but with much larger particles. Research is in progress into their potential in food nanotechnology sector including food packaging, foods and supplements due to their unique functions and applications of nanomaterials.3 Tens of millions of dollars are being spent in a global race to apply nanotechnologies in food production, processing and packaging.

The National Nanotechnology Initiative in the U.S. defines nanotechnology as the understanding and control of matter at a nanoscale where unique phenomena enable novel applications. Their extremely small size and high surface area are associated with their greater strength, stability and chemical and biological activities. Therefore, nanotechnology enables development of novel materials with a wide range of potential applications. Nanomaterials are used in a variety of consumer, medical, commercial and industrial products.[1] Because nanotechnology is an emerging, rapidly developing technology, very limited information about it is currently available.

What food technologists and engineers are doing to improve the safety of our food supply seems limited only by one’s imagination, and nanotechnology opens the door to a whole new array of products (Figure 1).

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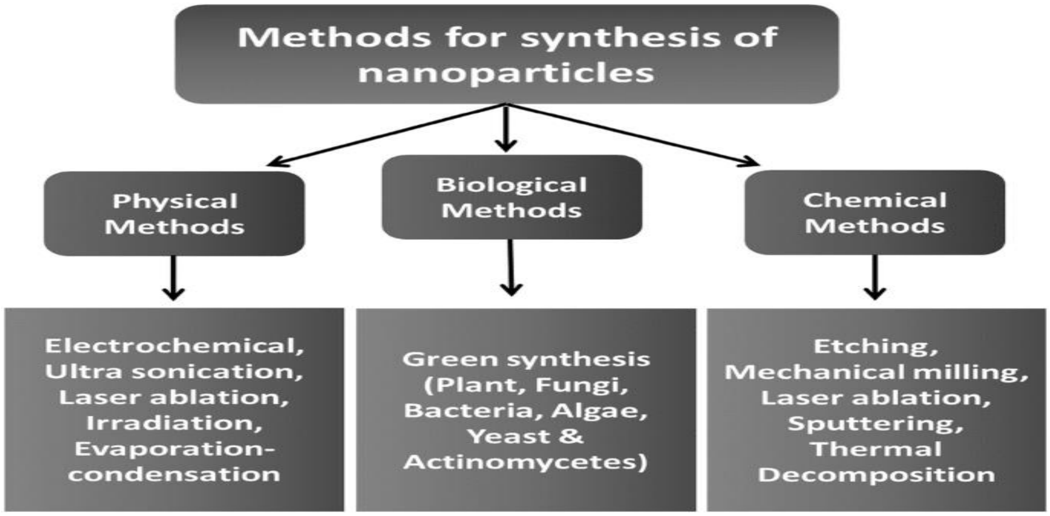
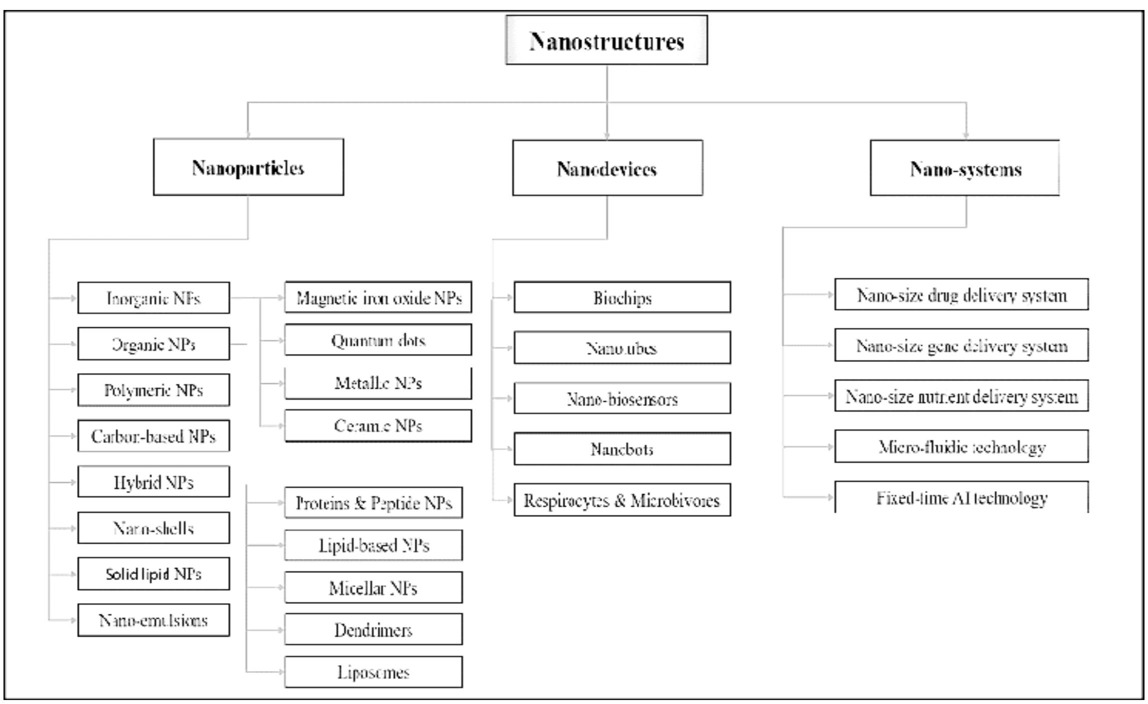


Fresh fruits, vegetables, meat and poultry products are potential vehicles for the transmission of human pathogens leading to foodborne disease outbreaks,[2] which draw public attention to food safety.

Therefore, there is a need to develop new antimicrobials to ensure food safety. Because of the antimicrobial properties of nanomaterials, nanotechnology offers great potential for novel antimicrobial agents for the food and food-related industries. The use of nano-antimicrobial agents added directly to foods or through antimicrobial packaging is an effective approach.

II. TYPES OF NANOMATERIAL



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III. METHODS TO PREPARE NANOPARTICLES

1.Methods of Synthesis of Nanoparticles
1.Types of Nanoparticles

Types	Size	Methods	Characteristic	Applications	References
Polymeric nanoparticles	20–1,000 nm	Solvent evaporation, dialysis, salting-out, supercritical fluid technology, interfacial polymerization, miniemulsion, microemulsion, and surfactant-free emulsion	Biodegradable, biocompatible, and provide complete drug protection	Increase the quality of food matrices, reduce nutritional losses, add new flavor or texture, retain aroma, enhance the stability, functionality, and absorption of active compounds	Rao & Geckeler, 2011; Sabliov & Astete, 2015; Yu et al., 2018; Rahman, 2019
Liposomes	50–100 nm	High-pressure homogenization, reversed-phase evaporation, colloid mill, depletion of mixed detergent lipid micelles, microfluidization, heat treatment (mozafari method)	Liquid state at room temperature; number of bilayers and size like unilamellar vesicles (ULVs), multilamellar vesicles (MLVs), and oligolamellar vesicles (OPVs)	Provide greater chemical stability and security to sensitive bioactive such as glutathione and ascorbic acid at high water-activity conditions, used as a release of antimicrobials upon pH changes	Fathi et al., 2012; Yu et al., 2018
Solid lipid nanoparticles	50–500 nm	Hot homogenization, cold homogenization, ultrasonication, ultrasonic-solvent evaporation emulsification	Minute size, larger surface area, high drug loading and the interfacial interaction of phases; highly ordered crystalline structure	Fortifying food systems, functional foods development, delivery of water-soluble, lipophilic	Musicanti & Gasco, 2012; Mukherjee et al., 2009; Ghanbarzadeh et al., 2019
Nanostructure lipid carrier	Less than 200 nm	Cold homogenization, hot homogenization, ultrasonication, ultrasonic-solvent evaporation-emulsification	Less organized structure, lower chance of burst release, superior bioactive loading capacity	Encapsulation of water-soluble and insoluble bioactive food compounds	Fathi et al., 2012; Ghanbarzadeh et al., 2019; Chinsriwongkul et al., 2012
Carbon-based nanocarriers	0.5–3 nm (diameter), 20–1,000 nm (length)	Laser ablation, arc discharge, and chemical vapor deposition	Geometric cage-like structures composed of pentagonal and hexagonal carbon faces found in fullerenes	Detection of nickel in food through nanotubes, used in water disinfection and	Yu et al., 2018; Zaytseva & Neumann, 2016

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				antimicrobial surface coating	
Dendrimer	<10 nm	Divergent method and convergent method	Radially symmetric highly branched molecules with well-defined, homogeneous, and monodispersed structure	Useful in the biomedical field, anticancer drugs, gene delivery, targeted delivery of bioactive compounds to macrophages	Yu et al., 2018; Abbasi et al., 2014
Nanocrystals QDs	1–10 nm.	Colloidal synthesis, hot-injection method, heat-up method, cluster-assisted method, microwave-assisted method	The color emitted depends upon QD size, narrow emission, bright fluorescence, high photostability, and broad UV excitation	Detection of pathogenic bacteria, and proteins, cell tracking and intracellular delivery, tagging of protein with QDs	Yu et al., 2018; Bonilla et al., 2016; Sinatra et al., 2017
Silver nanoparticles	1–100 nm	Gamma irradiation, laser ablation, electron irradiation, photochemical methods, microwave processing, chemical reduction, and synthetic biological methods	Optical, antimicrobial, and electrical properties depend upon size and shape	Applied as antimicrobials in foods, packaging and coatings	Iravani et al., 2014; McClements & Xiao, 2017
Iron oxide nanoparticles	5–50 nm	Thermal decomposition, microemulsion, hydrothermal, laser-induced pyrolysis, gas-phase deposition, protein-mediated	Extremely reactive with oxidizing agents, surface-to-volume ratio, superparamagnetism, higher surface area, and easy separation methodology.	Increased lightness and brightness in candies, chewing gums, bakery goods, milk powders	McClements & Xiao, 2017; Ali et al., 2016

IV. OPPORTUNITIES POTENTIAL FOOD APPLICATIONS

- Nanoparticles in Foods
- Food Contact Materials Foods
- Indirect Food Applications of Nanotechnology
- Computing and Communications
- Material Science
- Nanosensors
- Food Packaging

Nanotechnology in food preservation

Nanoscience emerges from the understanding of physical and chemical processes at the molecular or atomic level. The NANOFOODS initiative focused on translating such knowledge into food preservation.

Based on this, the EU-funded 'Development of foods containing nanoencapsulated ingredient' (NANOFOODS) project proposed to adopt tailored nanocapsule technology to preserve food bioactive compounds during processing and storage. As seen on the project website , partners were particularly interested in the bioactive compounds with potential anti-inflammatory activity, such as omega-3 fatty acids, butyrate and silymarin complex.
A series of prototypes of micro-encapsulated compounds were developed using different combinations of core and capsule materials. Omega-3, encapsulated in starch complexes and integrated in a food product, should survive storage until the time of consumption.

To translate the pilot-scale technology to industrial production, partners explored methods of nanocapsule freeze-drying and spray-drying. Different starch–omega-3 complexes were physically characterised with regard to thermal and oxidative stability. Their functionality in simulated gastrointestinal tract conditions was also evaluated by exposing complexes to extreme pH conditions and enzymatic digestion. The next step was to incorporate these bioactive nano-encapsulated omega-3 fatty acids and silymarins to generate novel foods such as pasta or dough for bread. Testing of these food products on patients with inflammatory bowel disease (IBD) or ulcerative colitis revealed an amelioration of the inflammatory status, indicating a beneficial effect. Overall, the NANOFOODS project successfully exemplified the improvement in the processing stability of bioactive ingredients including silymarins and polyunsaturated fatty acids (PUFAs) through nano-encapsulation. The NANOFOODS approach could satisfy the requirements for food products with enhanced nutritional value, quality and safety

Food processing

Food processing is a combination of several unit operations starting from the procurement of raw materials, sorting and grading, primary processing, packaging, transportation, and storage. The major deliverables of processing of foods are enhancing palatability, toxin removal, deactivation of enzymes, spoilage organisms, pathogens, and further fortification and enrichment with micronutrients if applicable. As there are numerous unit operations involved in a wide variety of raw materials and end products, there is a huge opportunity of improvements in most of the operations by the intervention of nanotechnology-based applications.
The application of nanotechnology in food processing can be broadly classified as "direct" and "indirect" usage. Direct applications mean direct incorporation of nanosized substances in the food matrix along with the declaration as such. The direct applications mostly include mixing of fragrances, coloring agents, nanopreservatives, antioxidants, and bioactive compounds such as vitamins, fatty acids, polyphenols, and so on. Indirect application comprises the usage of nanosized substances in the packaging material, nanosensors, and catalysts in hydrogenation of fats. The foods in which nanostructures are indirectly applied subsequently come in direct application to the food such as fats and oils hydrogenated with nanostructured catalysts finally find their way in the direct application of foods. The existing direct and indirect applications of the nanotechnology in food processing have further been divided into several categories as structural modification, application of heavy metal nanoparticles, nanosized food additives, inorganic nanomaterials, nanocoatings, and so on. The major findings in this regard are briefly discussed below.

Structural modification of foods

The presence of fat gives a typical mouthfeel to the consumers, which is only found in fat-rich products. Fat-rich products are not a healthy option for all the masses; hence, nanostructured lipids have been introduced to mimic the creamy texture of the foods for novel taste and rheological and tribological properties. These nanostructures find their application in nanostructured mayonnaise, frozen desserts, ice creams, and dairy spreads, which consist of low fat but there is no dissimilarity in the taste from the conventional fat-rich product providing a healthier option to the consumers.

Nanoencapsulated food additives

As rheological and biochemical modifications including sulfite hypersensitive reaction, nitrate toxicity, neurological harm, reason mood tantrums, and disruptive behaviors start inside the food matrix after the addition of conventional preservatives. The packing of substances at nanoscale in nanosized companies is called nanoencapsulation. Nanoencapsulated food additives save you any undesirable exchange in food cloth because of reduced utilization of salt, fat, sugar, and chemical preservatives and open up opportunities of sequential launch of a couple of bioactive elements. Nanoencapsulated components (synthetic lycopene, benzoic acid, omega-three fatty acids, isoflavones, and enzymes) locate more than one

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applications in useful food due to improved sensory recognition, uptake, absorption, and bioavailability of micronutrients, nutraceuticals, and all the nutritional dietary supplements brought via it . Nanostructures can also alter the dispersability of fat-soluble food additives. these nanostructured functional compounds are encapsulated in oil-based carriers (liposomes) or protein-based vendors (micelles). The nanocarriers can assist in safety from thermal degradation and in overlaying off flavors of peculiar meals additives. some of the commercially to be had nanoencapsulated meals components are lycopene, citric acid, ascorbic acid, benzoic acid, omega-3 and omega-6 fatty acids, fat-soluble vitamins A and E, isoflavones, lutein, and ß-carotene.4.1.3 Inorganic nanomaterials

Nan-materials of several transition metals and their oxides (e.g., silver, titanium dioxide, and iron), nonmetals (e.g., selenium and silicates), and alkaline earth metals (e.g., calcium and magnesium) find direct applications in health food products. Nanoselenium is being marketed as a tea additive with proclaimed higher antioxidant activity and redox balance. SiO_2 (E551), TiO_2 (E171), and MgO (E530) are permitted by the U.S. Food and Drug Administration (FDA) as anticaking agent, food color additives, and food flavor carriers. Gums, cake icings, candies, pies, puddings, and white sauces are incorporated with TiO_2 (E171) as a coloring substance . Leading food processing companies such as Kellogg's, Coca Cola Unilever, and Nestlé have commercially adopted titanium dioxide nanoparticles as whitening and brightening agent.

Heavy metal nanoparticles

Heavy metals have already been a part of the conventional food applications. Silver nanoparticle can be used as an antimicrobial agent, an antiodorant, and as a source of micronutrient . Its application is even gaining importance in health foods and antimicrobial packaging. In some research have found its application as an antibacterial agent for wheat flour. As observed aluminosilicate nanoparticles to be suitable for anticaking additives as well.

Food packaging

Packaging is an necessary a part of meals processing, because it affords protection to the meals from extrinsic elements (temperature, humidity, microbial infection, atmospheric gaseous combination, and so forth.) spill proofing, and tempering. It performs a pivotal position in dissemination of data concerning the serving size, nutritional content, and branding a few of the consumers. With the improved functionalities of nanostructured, metals, nonmetals, and its oxides, application of nanotechnology is continuously deepening within the meals packaging zone. Direct applications of nanotechnology in foods and beverages are below scrutiny; indirect packages in meals packaging have already turn out to be a reality. The applications of nanoparticles in packaging materials may be mainly categorized into following classes.

Improved mechanical and barrier properties:

Nanoclay is the leading nanomaterial to be explored for the enhanced mechanical and barrier properties as it can be incorporated in the conventional food packaging materials at relatively lower costs. FDA has provided "Generally recommended as safe" certification to bentonite and montmorillonite and listed them in Effective Food Contact Substance. Plastic polymers have been embedded with nanoclay particles for enhanced gas-barrier properties, with nanoparticles of silver and zinc oxide for antimicrobial activities, and with nanoparticles of titanium dioxide and nitrides for UV protection and mechanical strength, respectively.

Active packaging materials with improved antimicrobial properties

Active packaging substances are in better resonance with meals merchandise and that they respond to the converting extrinsic parameters during garage. They paintings both by way of releasing proper energetic molecules or by using scavenging the damaging additives. those tiny interventions have outstanding influence at the shelf existence of food merchandise. The generally used active packaging substances encompass oxygen and ethylene scavengers, moisture absorbents, enzyme immobilizers, and antimicrobial nanoparticles. Graveland-Bikkera and De Kruif (2006) stated the application of nanotechnology in food packaging for controlled release of functional debris from the nanocomposites to reveal the migration of minerals, probiotics, and micronutrients in meals. Degant and Schwechten (2002) and Sherman (2012) determined that the usage of silver nanoparticles in packaging substances extended the shelf lifestyles of meals through killing microorganisms at the floor in only 6 min. Nylon nanocomposite may be used to improve oxygen and CO2 barrier homes and additionally scavenge foul odor from the meals. Kumar and Münstedt (2005) discovered the antimicrobial homes of silver nanoparticles against Gram-fine and Gram-bad micro organism, yeast and molds, protozoa, and sure viruses. Diaz-Visurraga et al. (2010)

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attributed the antimicrobial houses of metallic nanoparticles to exposed surface vicinity, form, size, particle internalization, and chemical functionalities. The applications of antimicrobial nanomaterial in food packaging are reported in below Table.

2.Antimicrobial nanomaterials applicable to active food packaging systems

Nano materials	Embedding polymers	Sample/Medium	Results	References
Silver nanoparticles (AgNPs)	Polyamide6 (PA6)	Water	PA6/AgNP nanocomposite containing 0.06 wt% Ag completely eliminated *E. coli* in water	Damm, Münstedt, & Rösch, 2008
Silver nanoparticles (AgNPs)	Chitosan	Luriae–Bertani medium	2.15% (w/w) of AgNPs in the composite was enough to significantly enhance inactivation of *E. coli* in Luriae–Bertani medium.	Sanpui, Murugadoss, Prasad, Ghosh, & Chattopadhyay, 2008
Silver nanoparticles (AgNPs)	Sodium alginate film	Alginate film	Clear zones were observed around the AgNP-loaded alginate film samples inactivating both *E. coli* and *S. aureus* on alginate film.	Fayaz, Balaji, Girilal, Kalaichelvant, & Venkatesan, 2009
Silver nanoparticles (AgNPs)	Sodium alginate film	Carrots and pears	Increased the shelf life of surface sterilized carrots and pears up to 10 days.	Fayaz et al., 2009
Titanium oxide nanoparticles (TiO_2)	Oriented polypropylene (OPP)	Fresh Lettuce	Fresh lettuce exposed to UV light and coated with TiO_2 nanoparticles had its *E. coli* contamination decreased from 6.4 to 4.9 log CFU/g.	Chawengkijwanich & Hayata, 2008
Titanium oxide nanoparticles (TiO_2)	Titanium acid ester	Luriae–Bertani medium	The TiO_2-incorporated PE films showed effectiveness against *S. aureus* (Gram-positive) than *E. coli* (Gram-negative) in Luriae–Bertani medium.	Xing et al., 2012
Zinc oxide (ZnO)	Low-density polyethylene (LDPE)	Orange juice	The shelf life of orange juice was increased to 3 weeks, without impairing its sensory quality.	Emamifar, Kadivar, Shahedi, & Soleimanian-Zad, 2010
Zinc oxide (ZnO)	Chitosan nanostructures and polyvinylalcohol (PVA)	Nutrient Agar	*E. coli* and *C. albicans* growth were completely inhibited at composite concentrations of 110 and 160 mg/mL, respectively.	Wang et al., 2012
Silver nanoparticles	Montmorillonites	Kiwi-pineapple salad	Silver montmorillonites particles on cut kiwi fruits increased their shelf life up to 10 days.	Costa, Conte, Buonocore, & Del Nobile, 2011
Zinc oxide (ZnO)	Gelatin	Tuna fish	The composite film inhibited lipid peroxidase.	Kim et al., 2020

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Silver nanoparticles	Banana blend films	Water and glycerol (plasticizer)	The composite nanofilms have antimicrobial activity against *E. coli* and *L. monocytogenes*.	Orsuwan, Shankar, Wang, Sothornvit, & Rhim, 2016
Nisin	Pectin	Deionized water and NaOH for pH balance	Nisin-loaded pectin nanoparticles showed antimicrobial activity against Gram-positive (*Arthrobacter* sp. and *Bacillus subtilis*) and Gram-negative (*E. coli* and *Klebsiella* sp.) bacteria.	Krivorotova et al., 2016
Sulfur nanoparticles (SNP)	Chitosan	Acetic acid and glycerol (plasticizer)	The chitosan/SNP nanocomposite films showed antimicrobial activity against food-borne pathogenic bacteria, *E. coli* and *L. monocytogenes*.	Shankar & Rhim, 2018
Silver nanoparticles	Wild mushroom species *Ganoderma sessiliforme*	–	Nanoparticles showed antimicrobial properties due to AgNO3 and anticancer activity due to *G. sessiliforme*.	Mohanta et al., 2018
Zinc oxide nanoparticles	LDPE	NaOH solution and 2-propanol	LDPE/ZnO nanocomposites are capable to provide antimicrobial properties against *E. coli* due to Zn cations released.	Rojas et al., 2019
Soybean polysaccharide	Nisin	Tomato juice	Confirmed antimicrobial activity against *Listeria monocytogenes* and *B. subtilis*.	Luo et al., 2020
Titanium oxide nanoparticles (TiO_2)	Poly lactic acid (PLA)	Pork	0.4% of TiO_2/PLA showed highest antimicrobial activity.	Li et al., 2020

Edible coatings and self-cleaning nanomaterials

Nanosilver-lined vegetables and fruits remain energetic at some point of transportation and garage methods because of the altered respiratory mechanism. Heavy metal nanoparticles are being examined as part of fit to be eaten coating substances for more desirable uptake and bioavailability. The self-cleaning nanomaterials are an emerging studies fashion due to the radical self-cleaning functionalities attributed by way of the nanocomposites in positive storage situations. Flores-Lopez et al. (2016) stated that moisture, CO2, water, and oxygen barrier properties can be advanced through application of thinner hybrid edible films of thickness less than 100 μm, which also improves the shelf lifestyles and sensory characteristics of meals merchandise.

Smart packaging nanosensors

Sahoo et al. (2018) rumored concerning the detection and isolation of many pesticides, as well as aldrin, glyphosate, atrazine, and tetradifon victimisation changed metallic element oxides as a result of the photocatalytic interactions throughout storage. Nanosensors are rising as associate degree emphatic tool to neatly monitor the interactions of the food and packaging materials within the storage.

Food preservation:

The agricultural raw materials bear a vast chain of process and contamination with spoilage and unhealthful microorganisms; thus, there's perpetually a risk of widespread foodborne illness. Detection and sterilization of microorganisms is that the solely thanks to win food preservation. The delayed identification and quantification of poisons, spoilage or unhealthful organisms, and time period estimation square measure the traditional hurdles that require to be addressed with the rising novel technologies. Current poison detection ways are intervened with nanotechnology-based ways to expedite the method at lowest prices, movability, and easy least detection limits to eliminate long-run biological terrorism problems. Nanoparticle-based colorimetrical assays and molecular mimicry are explored for poison detection and created positive ends up in epidemic cholera poison detection. Stanković et al. achieved success in isolation of single microorganism detection by fluorescent-based quantification of bacterium victimization antibody-doped oxide nanoparticles in but twenty min. Detection of single E. coli O157:H7, together with enterobacteria and Bacilli species, was conjointly created attainable in beef samples closing its effectivity for each gram-positive and gram-negative species. This analytical approach reduced the normal plating technique of 16–18 60 minutes to couple of minutes and it might even notice the presence of individual cellular contaminations, that is much tough to realize victimization standard ways. Antimicrobial applications of silver nanoparticles are established while not sterilisation drug resistance. Silver nanoparticles-based food containers have already been in apply providing high-quality foods for extended period and thus reducing wastage of foods. Nanotechnology-based interventions in food preservation have drastically improved detection sensitivity and reduced standard toil of detection. It will even mask unpleasant odors cathartic as a results of multiple food process unit operations

The automation and manage of any operation is as economical as its sensing. The actual-time and in place sensing of dynamic parameters area unit of overriding importance as they embellish the system operations. it's miles as a result utmost crucial to broaden a speedy tracing mechanism to isolate the contaminated product as a result of it enhances the meals protection and assures customers' health. customers endlessly imply the scientific facts of food producing, processing, and storage conditions to be declared on ingredients and consequently systematic recording of all facts is of overriding importance. The mixture era of biological science, organic chemistry, and nanoscience exposes a brand new size in quick and faraway sensing and recording of analytical potential parameters. food poisoning and food poisoning area unit the key drivers to expedite the search of nanosensor-primarily based mostly chance poisonous substance detection techniques. The detection of infection before proliferation in raw meals, processed meals, or animal feed is that the elementary leap achieved by approach of this mixture generation. Molecular mimetics and aptamers are enclosed on this thread. Goldschmidt settled out that the incorporation of fluorophores and QDs extensively diminished the instrumentation size and increased sensitivity of detection. Detection of serious metals, particulates, pathogens, toxins, allergens, nonnutritional parts, and accidental factors (light, humidity, temperature and lots of others.) is that the capability utility of biotechnology-based nanosensors.

As a leap forward in detection limits, nanosensors are capable of detecting several contaminants and toxicants at the identical time at highly lower price and generating least effluents to discard. it's miles mentioned the suitability of nanosensors in detection of toxins and pathogens in packaging materials using nanosensors. Vo-Dinh, Cullum, and Stokes (2001) observed out the utility of nanosensors in evaluation of flavors, consuming water, and scientific diagnostics. Plexus Institute 2009 added the nanostructured luminescent transducer devices for evaluation of potable water. It developed a low-cost nanostructured bioluminescent spray that could glow at the account of microbial infection, thereby indicating its unsuitability of use. Escherichia coli changed into detected the usage of a nanocantilever-based totally fast biosensor with blended efforts of micromechanical oscillators and nanotechnology . It delivered down the detection time of Gram-terrible traces to as low as 1 hr, that is substantially decrease than conventional plating approach. The nanocantilever proved efficient in detection of physical parameters consisting of temperature, floor anxiety, and mass additionally. multiple cantilevers of various molecular recognitions in aggregate installed on a unmarried electronic chip may be used to stumble on pollutants and microbial infection concurrently . Molecular imprinted nanostructured polymers are being developed to quantify each small molecules and macromolecules for food quality control. Nanoparticles with silica core can be used for detection of tert-butylhydroquinone in food samples. Nanosensors based on molecular fingerprinting on polymers may be developed for detecting glucose, acids, antioxidants, and. Nanobarcodes for meals authenticity have already been commercially ordinary. Nanostructured tracing gadgets can consolidate several devices that grant information related to sensing of allergens, pathogens, spoilage organisms, pesticide residues, veterinary drug residues, and to be had vitamins in food. Nanotechnology-enabled tagging gadgets may be available in deeper evaluation of product records. Such programs in full fledge industrial applications can rule out the threat of information breach and might offer consumers all the scientific records of product from farm to fork. it may assist in coping with disaster conditions as there's huge danger associated in delivery chain of all of the ingredients.

Nanoceuticals:

Nanotechnology technology contains an array of food and nutritional supplements referred as nutraceuticals which might be transformed to bio-superior "Nanoceuticals". As India's economic system is booming and buy is at the upward push, India's nutraceuticals market is anticipated to reach round US$4 billion by means of 2018.those merchandise discover abundant area

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to expand their therapeutic phase at lab scale, however, their translation to clinics often has ended in a failure. Latter being assigned to the bad bioavailability of these nutraceuticals, attributed to their terrible solubility and permeability, picture-degradation and decrease to be had systemic concentrations. Nanoprocessing of these products may also boom their therapeutic price and offer protection from free radical harm. further, it complements their antimutagenic capacity, provides higher neurological functioning, improves endocrine and immunomodulatory capabilities, further to metabolism and digestion, and possesses better anti-growing old houses, due to improved bioavailability. although no alteration inside the chemical structure of the nutrient happens, however a trade in its movement for better utilisation and absorption in the frame is regarded as a result of this translation.

a nano-transformation is visioned as a result of approvals from US-FDA that is in any other case sought to be the important milestone for commercialisation of the nano-based product. The Indian marketplace is flooded with a range of nanoceutical merchandise which might be introduced thru numerous nanodelivery systems along with polymeric and lipidic nanoparticles, micelles, phospholipid complexes and the equal is expected to rise within the coming years. As keeping a very good fitness is our prima-facie responsibility, the shortcomings of the technology must be understood. This e-book chapter exposes the successful adventure for reworking a nutraceutical to nanoceutical and their effect on fitness of the individual.

5.CHALLENGES AND TECHNOLOGICAL CONSTRAINTS

Even though nanotechnology has a amazing ability to manufacture revolutionary merchandise and strategies inside the food area, there are numerous hurdles. The major factor is to supply fit to be eaten transport structures the use of financial processing operations with effective formula for human intake and safety . The migration and leaching of nanoparticles from packaging substances into meals merchandise is of great challenge to make certain the wholesomeness of foods. The NSMs both immediately or circuitously introduced are from time to time been isolated because of migration from different sources). The materials behave as totally one of a kind at nanoscale and we still have restrained technical knowhow of its evaluation. The whole expertise of nanoscale functionalities and toxicities of nanomaterials will in addition augment to its realistic utility and safety policies.

Effects of nanoparticles, capacity hazard, and associated toxicity troubles and surroundings issues need to be addressed. Nanoparticles crossing the organic barrier and entering in cells and organs were mentioned. Synthesis of nanoparticles the usage of exceptional chemical methods has also negative effects and generates risky non-ecofriendly via-merchandise that cause excessive environmental pollutants. therefore, apart from recognition and public demand, an inclusive hazard assessment program, regulatory coverage, biosafety, and public worries need to be considered even as processing, packaging, and human consumption of nano-based totally food products. furthermore, in vitro and in vivo research concerning nanoparticle interactions with residing beings are wished previous to commercial utility and for manufacturing of antibacterial nanoparticles with surroundings pleasant.

Results of nanoparticles, potential chance, and associated toxicity troubles and environment issues must be addressed. Nanoparticles crossing the biological barrier and coming into in cells and organs were suggested. Synthesis of nanoparticles the use of exclusive chemical methods has also unfavourable results and generates unsafe non-ecofriendly through-products that reason extreme environmental pollution. therefore, apart from popularity and public demand, an inclusive risk assessment program, regulatory policy, biosafety, and public concerns should be taken into consideration while processing, packaging, and human consumption of nano-based meals products. moreover, in vitro and in vivo research related to nanoparticle interactions with residing beings are wanted prior to business application and for manufacturing of antibacterial nanoparticles with surroundings friendly.

6.THE SAFETY ISSUES: REGULATIONS

In the United States, the US Food and Drug Administration (FDA) require manufacturers to demonstrate that the food ingredients and food products are not harmful to health, yet this regulation does not "specifically" cover nanoparticles, which could become harmful only in nanosized applications. Thus no special regulations exist for the use of nanotechnology in the food industry[104]. In contrast, the European Union has recommended special regulations that have yet to be accepted and enforced. The FDA says that it regulates "products, not technologies." Nevertheless, FDA expects that many products of nanotechnology will come under the jurisdiction of many of its centers; thus, the Office of Combination Products will likely absorb any relevant responsibilities.[105] Because FDA regulates on a product-by-product basis, it emphasizes that many

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products that are already under regulation contain particles in the nanoscale range. Accordingly, "particle size is not the issue," and any new materials will be subjected to the customary battery of safety tests.

The Institute of Food Science and Technology (IFST), a United Kingdom–based independent professional body for food scientists and technologists, has a different view of nanotechnology. In its report,[106] the organization says that size matters and recommends that nanoparticles be treated as potentially harmful until testing proves otherwise. Still, it is the European Commission's intention to apply existing food laws to food products using nanotechnology. Consequently, the European Commission says that the technology will likely require some modification for it to adhere to existing laws.

Commissioned by the UK to assess the potential effects of nanotechnology, the Royal Society and the Royal Academy of Engineering recommend indicating nanoparticles in the lists of ingredients. The UK government agrees that the inclusion of nanoparticles on ingredient labels is necessary for consumers to make informed decisions; thus, updated ingredient labeling requirements will be necessary.[107] The UK government plans to consult with its EU partners to determine whether IFST's recommendation to scrutinize nanoparticle ingredients for safety is valid.

TA-Swiss, the Swiss center for technology assessment, has recently analyzed the situation concerning nanotechnologies and food in Switzerland,[108] considering in particular food additives that have been used in Switzerland for many years (e.g., carotenoids, micelles, and silicon dioxide). Although according to the TA-Swiss study, there are no indications at this time that nanoparticles are used in Switzerland that have been shown to be dangerous to human health, in most cases no specific tests have been conducted to clarify possible new risks depending on particle size. Similar to any other industry sector, the current lack of methodologies and guidelines on how to assess potential risks emanating from certain substances at the nanoscale complicates risk assessment in the food sector.

The regulatory system for food additives in Switzerland sticks to the so-called "positive principle." Food additives may only be used if they have been tested and appear on a positive list, identifiable by an E-number. In Switzerland, silicon dioxide (E 551), iron oxide (E172), titanium dioxide (E 171), silver (E 174), gold (E 175), and aluminium (E 173) are registered and on the positive list of food additives. These substances may be used in certain foods according to the standard of "Good Production Practice."[109] Most food additives on the positive list, however, have only been used and tested in the macroscale form so far. Because particle size is not a relevant criterion to distinguish substances in safety tests (yet), the nanoscale form of these substances is implicitly admitted too. This problem also exists concerning, e.g., chemicals legislation or information disclosure obligations through material safety data sheets.

An emerging trend in food packaging makes use of silver's antibacterial properties by implementing silver nanoparticles into food containers. Using fresh strawberries, the test series clearly demonstrated that the silver-coated food container reduced mould growth. Critics, however, argue that it is not yet clearly understood whether and how nanoparticles might pass out of the packaging into the food, and what effects they might exhibit once they have been ingested.

Even if such nanosilver applications might not be available at this time in Switzerland's stores, with the possibility to globally order goods over the Internet, products with less stringent or different safety standards are readily available to consumers. Particularly in the food sector, it will be of utmost importance to deal with the mentioned safety issues in an early phase in order to avoid harsh consumer (over)reactions.

There are several generic issues related to regulation, labeling, and approval of nanoproducts:

- In the UK the Royal Society and the Royal Academy of Engineering produced a report on nanotechnology. They identified a lack of knowledge on the bioaccumulation and toxicity of nanoparticles. Based on this they suggested caution in the use of nanoparticles in consumer products until more information was available on their safety.
- Although regulatory authorities agree with the need to be cautious in the use of new technologies such as nanotechnology, they anticipate that most applications of nanotechnology in food to be considered for approval will be safe and beneficial to the consumer. It is generally suggested that there is a need to evaluate new products on a case-by-case basis and then consider any necessary amendment of regulations. They reason that they could not ban a nanoproduct unless there was some evidence that the product was actually harmful. Such an approach to regulation could be perceived by consumers as a loophole that could allow industry to introduce products onto the market without adequate testing or approval. Given the ambiguity of the status of the use of nanoparticles of food-approved ingredients or additives in food or food contact materials, the authorities responsible for regulation should make clear statements about their use and that they consider

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that new products based on the use of added manufactured nanoparticles in food or food contact materials should be regarded as novel products, requiring evaluation and approval.

- The attitude to regulation, labeling and approval of products of food nanotechnology varies from country to country. However, nanoproducts are becoming widely available through the Internet. The lack of consistency in regulation, labeling, and approval of such products makes it difficult for consumers to exercise choice in a rational manner.
- Consumer attitudes are likely to be vital to the successful application of nanotechnology in the food industry. Given the lessons of the genetically modified (GM) debate in the UK and Europe, it is important that the benefits and risks of nanotechnology are openly discussed, and that it is important to consider the issue of labeling. In particular, the use of the term "nano" or related terms as part of the branding of a product is at present ill defined. It would be useful if regulators provided guidelines as to when such branding was appropriate and justified. Where the term "nano" is used, there should be a requirement that producers define how nanotechnology has been used in the development of the product, and why this process enhances the quality of the product.
- Special attention should be given to novel uses of nanoparticles as antimicrobial agents on surfaces such as cutting boards, refrigerators, or utensils. The key questions here are whether such materials are released on contact with food, whether they are ingested, and if they are, their impact on human health and the acceptable levels of intake of such materials on a daily basis. New applications such as the use of nanoparticles as antimicrobial agents in edible films and coatings are likely to arise in the future and will raise new issues on the ingestion, accumulation and safety of such products.
- Further research is needed on the consequences of nanoparticle ingestion. There is a particular need to study substances that are not normally adsorbed, digested or metabolized upon ingestion. For these materials, studies need to consider the effect of size on bioaccumulation and toxicity of such particles, as well as the benefits and risks of antibacterial effects on oral and intestinal microbial ecology. Further research is needed on the consequences of nanoparticle ingestion. There is a particular need to study substances that are not normally adsorbed, digested or metabolized upon ingestion. For these materials, studies need to consider the effect of size on bioaccumulation and toxicity of such particles, as well as the benefits and risks of antibacterial effects on oral and intestinal microbial ecology.
- The consequences of using nanotechnology to improve the bioavailability of nutrients should be considered. This should take into account the safety of the product, the consequences of increased or altered metabolism, and the need for labeling, regulation, and validation of health claims for such food supplements.
- Selective or clear labeling of these nanoparticles may be required if the safety data or ADI of nanoparticles produced from food approved ingredients or additives differ from that of bulk materials.

V. POTENTIAL FOR COMMERCIALIZATION AND FUTURE PROSPECTS

significant advances had been made inside the software of nanotechnology in food technological know-how and research. Nanotechnology tracks monitoring surveillance that may assist hit upon pollutants, pathogens and pesticides and make certain meals fine is maintained. the availability of skilled employees, the fee of analysis, and the procurement of technical equipment aren't limitations to nanotechnology. however, some nanosystems are nevertheless of their infancy or are being advanced as powerful nanocomponents. For a wide variety of programs, you may do more full-size research in the following regions: on the same time, safety and demanding situations may be taken under consideration.

Modern ideas for "smart packaging", the development of antigen-unique biomarkers, and the fusion of nanoparticles for the manufacturing of nanocomposite polymer movies are gradually being realized. sizable studies paintings can be done for enlargement and destiny business programs. nanocomposites are CO2-neutral biodegradable molecules. therefore, their application to meals packaging materials can be applied in the near destiny. further, nanosilica can be explored for business use as a surface coating fabric for altered barrier houses).

Antigen-specific biomarkers usually help identify the presence of organisms that are causing food spoilage. Leveraging its usefulness in detecting food pathogens such as bacteria, viruses and mycotoxins through nanosensors (fast, accurate, effortless) is easy and fast.
Also important to consumers is the use of nanosensors in film packaging to detect the gas released as a result of food spoilage. Such sensors can detect spoilage at all stages of the food chain. This reduces overall food loss and provides similar benefits to food manufacturers, retailers and consumers.

Processed nanostructured or -textured food (e.g. less use of fat and emulsifiers, better taste)

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