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A Review on the Application of Nanotechnology in Food Industries

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Abstract

Nanotechnology has the potential to be used in the food business and processing as novel pathogen detection instruments, disease treatment delivery methods, food packaging, and bioactive component distribution to specific areas. Nanotechnology's implementation in food systems will bring new approaches to improving food safety and nutritional value. It sums up the capability of nanoparticles for their utilization in the food business to give purchasers a safe and tainting-free food and to guarantee the customer adequacy of the food with upgraded useful properties. With the increase in shelf life and enhanced quality, the edible packages or thin-film usage can delay the deterioration of food. To regulate the nanomaterials and applications in the food industry a legal basis has been made. The Organization of Economic Co-operation and Development (OECD) recommended the standard test guidelines be used for the hazard assessment of nanomaterials for chemical safety. Finally, nanotechnology supports the change of the existing food processing systems to attest the safety of the products, nurturing a healthy food, and also the food's nutritive quality to be enhanced. The straightforwardness of security issues and natural effect should be the need while managing the advancement of nanotechnology in food frameworks and hence mandatory testing of nano food varieties is expected before they are delivered to the market.

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Introduction

A nanoparticle is a tiny particle which ranges between 1 to 100 nanometers in size. It exhibits distinct physical and chemical properties and is undetectable to the human eye. The nanomaterials occur naturally, either as by-products of the

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combustion reaction or as by-products of being intentionally produced to perform peculiar functions. Because of the capability to produce the materials in a certain way to perform a peculiar role, the usage of nanomaterials scales across numerous varieties of industry. Based on the morphology, size, chemical, and physical properties of the nanoparticles, they can be classified into distinct types.[1] They are metal, carbon-based, ceramic, polymer, semiconductor, and lipid-based nanoparticles. In the past decade, food nanotechnology has grown into a markedly active site for research. Nanoparticles are not new to our food supply.[1] Nanostructures are naturally occurring nanostructures mainly to improve the functional behavior of food to make over the nanoparticles from food substances. Currently, the majority of nanotechnology's potential to enable new food items is still only a promise. Numerous areas of the food industry are using functionalized nanostructured materials, including the development of novel nano sensors, new packaging materials with enhanced mechanical and barrier properties, and effective and targeted nutrient delivery systems. There are numerous naturally associated nano-sized elements that are released with the foods we consume. Nanoparticles appear as an outcome of processing techniques similar to homogenization and milling, and there is also another probability such as the ingredients combination instinctively self-assembling into micelles, nanofibers, etc. As it may lead to innovations in food texture, taste, processability, and stability throughout the course of a shelf life, nanotechnology has the potential to transform the food system and have a beneficial impact on the science of food. In the light of the present review, it raises concern about risk assessment and also has the potential to develop the nutritional value of food-making over novel food products, new safe food packaging for extending the shelf life of food.

Food Nanotechnology

Nanotechnology has two approaches that are commonly used in the food industry: "bottom-up" and "top-down." The first approach is carried out by reducing the particle size during physical processing techniques like homogenization and milling. On the contrary, the second approach employs the ability of molecules to self-assemble[1] Globular proteins' folding and casein micelles' organization are examples of self-assembly in the "bottom-up" approach. Although nanofoods are still in their infancy, they have the potential to significantly improve food safety, create more nutritious and healthier foods, intensify flavor, or mask off-putting flavors. Recent applications of nanotechnology in foods allow for the unveiling of foodborne pathogens with nano-sensors or improved nutraceutical delivery with minimum bioavailability and accessibility. The nanoparticles mostly used are called colloids (i.e., micelles, emulsions, monolayers, and bilayers). And then, when the materials get modified, the colloids tend to be smaller than a micron, giving the nanoparticles modified physical and chemical properties that make them interact distinctly with the living systems and result in unexpected toxicity. Assured outcomes and usages are already being developed in the system of nutrient delivery areas with the means of bioactive nanoencapsulation, there are biosensors for the identification and assessment of pathogens, altering the food composition etc., And there is also edible film to conserve perishable foods such as fruits, vegetables, meat and baked goods which will increase their shelf life.[2]

Edible Thin Film Packaging

One of the major problems in food is maintaining its chemical-physical stability and the contamination due to microbes during storage. Due to the environmental and processing conditions the proteins, carbohydrates, lipids, and fat in food changes with time. With the increase in shelf life and enhanced quality, the edible packages or thin film usage can delay the deterioration of food. Some materials utilized in the generation of bioplastic for the application in edible packaging thin film are polylactic acid, gelatin, alginate, polyglycolic acid, blends of carrageenan, starch, sodium caseinate, and chitosan.[3] They can be utilized in the protection of meats, vegetables, chocolate, fruit, candies, and some goods that are baked because they act as active packaging which increases the barrier protection properties that prevent gasses like ethylene and oxygen from the damage of food and preserves the product's outer appearance.

Edible nanolaminates can be used to produce edible thin film that may protect the food against lipids, moisture, gasses, odor, and off-flavors. The materials like these can be formulated with proteins, polysaccharides and lipids. These films made with polysaccharides and proteins show good barrier properties against carbon dioxide and oxygen but they are not efficient enough to preserve moisture. The nanomaterials are developed by enhancing the thermal and mechanical properties so as to ensure that the foods are protected from external chemical, thermal, microbiological or mechanical effects.[4] Films made with lipids are suggested to protect the food from moisture, yet they propose bounded resistance to gasses as their mechanical strength is also poor. It is possible for the attachment of colloidal particles or charged lipids to edible films as nanolaminates which can constitute other functional agents like anti-browning, antimicrobials, antioxidants, enzymes, flavors and colors.

In some experiments studies were made to use hydroxypropyl starch and gelatin to make edible films and polyols and water to make plasticized. From this, they found that the permeability of gas was proportional to the plasticizer amount exhibiting a fascinating edible film for fruits.[3] Another edible film formulated by chitosan was associated with ready-to-eat roasted beef to control *Listeria monocytogenes*. These edible films were formulated by dissolving the chitosan in either acetic or lactic acid. Certain observation of the authors was, chitosan coating with acetic acid was more effective in reducing Listeria monocytogenes counts than which was made with lactic acid.[3]

Non-Edible packaging

Nanotechnology helps in reducing the pollution of the environment by the production of biodegradable packaging. Anyhow, the biodegradable material shows poor mechanical and barrier properties and they can be considerably improvised. The reincarnation of nanostructures such as layered silicates in the biodegradable material could enhance the mechanical properties, qualifying them as packaging material. In a review, researchers stated the unique functionalities of nano-bio composite films which enhances the gas, vapor and Ultra Violet (UV)-hindrance or maintained the released capacity of certain active agents for the bio-packaging of food. Durethan KU2-2601 packaging film, known as a ‘hybrid system’, developed by a well-known company, is enriched with a numerous number of silicate nanoparticles. They constrict the entry of oxygen, carbon dioxide and certain other gasses, and the exit of moisture, hence preventing the spoilage of food.[5] In the packaging area, silicate layers are another nanostructure used and their addition in a polymer matrix gradually accelerates the barrier property of the polymer and through their tortuous pathway they can control the rate of diffusion.[3] A composite erected of Gelidium-corneum–gelatin film with nano clay affixed while the film-forming solution exhibited excellent antimicrobial properties of the thymol-containing composite film as a packaging material for chicken breasts, which inhibits microbial growth during the storage period.

Another use of nanocomposites is producing antimicrobial packages which will expand the shelf life of food. The nanocomposites are formulated with the polymer reincarnating a nanostructure such as silver nanoparticles. Because of their antimicrobial properties, these particles are being utilized in the generation of packaging to hinder the growth of pathogens in meat or fresh food products. Biopolymer packaging materials show poor barrier and mechanical properties which makes their usage to be limited, but this can be overcome by nanocomposite technology.[1] A nanocomposite-postulated packaging material of a coalition of polyethylene with silver nanoparticles, nano-TiO2 (Titanium dioxide) and attapulgite clay protected green tea during a long storage period. Yet another tactic which is used for expanding the shelf life of food was the generation of a nano packaging based on polyvinyl chloride film with nano-ZnO (Zinc oxide) powder. The material was used for the conservation of apples, showing a constriction in polyphenol oxidase and pyrogallol peroxidase activities and dodging the degradation of fruit.[3]

Nano-Sensors

Many researches show that nanosensors that are incorporated in food packaging are being used in the detection of pathogens, chemicals and mycotoxins in the food materials.[6] Habitual control of these microorganisms, though more dependable, is complicated. Yet the nano biosensors are able to swiftly identify the pathogens and food toxins from farm to the finished product. Nanosensors are used to detect some common food contaminants such as E. coli, Listeria, Staphylococcus species and Salmonella that cause foodborne illnesses. A study showed that Staphylococcus sp. enterotoxin B can be sensed by a bilayer fluid membrane that is being reinforced to chips of poly (dimethyl siloxane) (PDMS).[6] A study showed that a nano biosensor coupled with a microgravimetric quartz crystal could be efficient in detecting E. coli. In this sensor, to amplify the signal, streptavidin-coated ferrofluid (Iron Oxide (Fe_3O_4) nanoparticles) was used.[3] One of the novel technologies used in packaging is intelligent packaging which contains a nano biosensor that helps to fluoresce different colors when the food products get in contact with pathogens. To identify the varieties of toxins, chemicals and pathogens, devices such as antibodies and nanowires have been developed. Further use of nanosensors is to distinguish the quality of foods like juice, wine, coffee and milk. Ultra-thin films arranged in a layered fashion were used to design the nano sensors.[3] Certain electronic sensors such as nose and tongue can be utilized in quality analyses of beverages and foods. An electronic nose was developed by smart packaging systems and it was included in their packaging system. It consisted of a cue of nano sensors, those being highly sensitive to gasses that are being released from the food as it degrades, leading to a change in the color of the sensor strip, which indicates a visual signal regarding the freshness of the food.[3]

Nanocellulose

The sensory, nutritional and physicochemical properties of food can be altered with nanocelluloses as they have the ability to create novel structures in food. They act as fat replacers or fillers, they tend to stabilize emulsions and foams, and they form gel networks as they self-assemble in aqueous solutions since they are able to absorb to oil-water or air-water interfaces.[7] Nanocelluloses can be used in combination with some food ingredients that are naturally present such as biopolymers or biosurfactants to extend the nanocellulose's chemical functionality. The predominant instance of nanomaterials which are from the sustainable plant-based, renewable and natural sources in Nanocellulose. Recently the need and the interest in finding novel plant-based ingredients for the replacement of synthetic or animal-based ingredients in food to meet the consumers' demand in having healthy and sustainable food products has gradually increased. The material suitable for this purpose will be the Nanocelluloses, as they can be utilized in the alteration of certain constituents like sensory, physicochemical, stability, texture and appearance of the food.[7]

Classification of Nanocelluloses

The two main classification of Nanocelluloses such as Cellulose Nano-Crystals (CNCs) and Cellulose Nano-Fibrils (CNFs) can be confined from some plant sources or wood by mechanical or chemical treatments like partially disrupting their natural structures.[8] CNCs are generally developed from fibers of the cellulose after the less-ordered elements are specifically removed from the source material, for instance by the use of constrained hydrolysis of acid, which leaves the crystalline elements complete. The nanoparticles resulting from this process are nanorods that are meticulous which shows increased crystallinity. CNFs are generally attained by breaking down the fibers' cell wall which uses high mechanical shear energy that leads to have longer particles and makes it less crystalline than the CNCs.[8]

Applications of Nanocellulose in Food

The Cellulose Nano-crystals and Cellulose Nano-Fibrils have amphiphilic characteristics since the crystalline cellulose has both the hydrophobic and hydrophilic faces. These nanocelluloses can be utilized to stabilize the foams and emulsions by absorbing the interfaces of air-water or oil-water since they have an amphiphilic character. The property to stabilize the emulsion depends on various factors such as length, thickness, surface charge and chemistry of the nanocelluloses. These nanocelluloses can be used to alter the texture of certain foods since they have the ability to self-assemble and associate element systems in the aqueous solution.[7] Coating and packaging materials can be made with these nanoparticles as they have the ability to produce good barrier properties since they generate elastic materials. For the replacement of fats in cream, soy protein and CNFs combination were utilized to produce gel-like materials. The characteristics of the texture of the decreased-fat cream is found to be similar with that of the available conventional creams as the optimized concentration of CNF used. The ice creams with low-calorie can be formulated with these decreased fat creams with possible texture. From this we can say that nanocelluloses are eminently pliable ingredients that have a high probability to be used in foods.

Nanocellulose Incorporated Packaging Material

Edible film formulated with Mango puree has improved its mechanical and barrier properties with the utilization of Cellulose Nano-Fibrils in it. Young's modulus and the tensile strength have been increased due to the presence of Cellulose Nano-Fibrils in it, which contributed mainly to the network formation within the matrix. The film's barrier properties were found to be improved as the addition of Cellulose Nano-Fibrils increased the sinuosity.[5]

These packaging films which comprise nanocellulose have got amazing oxygen barrier properties and have a huge impact on the shelf-life of processed and fresh foods, as they have the ability to generate compressed packed solids being held together due to strong bonding of hydrogen.[5] Due to the strong hydrogen bonding among the nanocellulose and biopolymers such as starch, and soy protein, it enhances the cohesiveness and depicts increased water resistance of the film generated from the biopolymers.[7]

Nanoencapsulation

Encapsulation is a method of enclosing delicate chemicals in a coating or a wall material. The wall material shields the delicate chemicals from harmful reactions and regulates their release. The word NANOENCAPSULATION refers to the use of layers, coverings, or simple micro dispersion to encapsulate on a nanoscale scale. The nanometer-scale encapsulation layer forms a protective covering on food or food molecules/ingredients. This approach can be used to protect bioactive substances including vitamins, antioxidants, proteins and carbohydrates as well as lipids, to improve the stability and functionality of functional foods.[2]

Classification

The systems of nanoencapsulation are classified into solid-liquid, liquid-liquid, and solid-solid systems. The Formation of nanoparticles can be done by two methods i.e., bottom-up and top-down approaches.

Liquid-Liquid System

The system is used in beverages, food and drinks where the mixing of oil and water phases is essential. Food elements such as tastes, omega-3 oils, and other sources of lipophilic media, have very low water solubility, ranging from 0.1 to 1 mg/ml. Active ingredient saturation solubility in water and oil phases, partition coefficient, flavor/food taste threshold, flavor/food aroma/odor threshold, and appropriate dose loading requirements for nutraceuticals such as omega-3 fish oil are some of the basic properties food scientists should consider before choosing a proper system for solubilization. Benzoic acid, ascorbic acid, astaxanthin, vitamin, rice bran oil, mint, coenzyme, and isoflavone are the list of food ingredients and flavor with low water solubility i.e., it signifies by using the method of Emulsion based Nanoparticle liquid-liquid system for New products.

Solid-Liquid System

In nanotechnology, Solid lipid nanoparticles are an expeditiously developing domain, possessing a high scale of applications in clinical medicine, drug delivery and research, additionally in other parts of sciences. The dimensions range between 50 and 1000 nm. The capacity to combine drugs to nanocarriers proposed a new sample, which is employed in drug targeting at tertiary and secondary levels. Hence, this type of nanoparticle system have seeked attention from most researchers and also it has a lot of potential in terms of achieving the goal of controlled and specific drug delivery.[9]

Solid-Solid System

In the case of solid-solid systems, the formulation normally begins with the creation of a nanoemulsion of the active component in a liquid state with the carrier shell material. Small droplets or fibers are formed by the atomization technique, followed by a precipitation stage to produce nanoencapsulated materials.

The benefits of Solid-solid system are High surface-to-volume ratio, resulting in a large surface area and improved bioavailability, Controlled flavor release with stimulus responsiveness, rapid dissolve, or burst effect, Surface morphology that is unique could help extend shelf life, Encapsulation of thermally labile materials may be possible using a near-room temperature technique.

Perspective and Trends

Nanoencapsulation is a process that originated in the pharmaceutical industry and has since been applied to the creation of nanofoods and similar products in the food industry. However, there are a number of concerns that must be addressed before such an application can be extensively used by industry and consumers. National bodies are likely to enhance initiatives to control, administer, and promote proper development of nano-sized food-related items as regulatory issues on nanofoods are still being created.[10]

Nanofluids

Nanofluids refer to the fluid containing nano-sized particles(1-100 nm). There are two phases of nanofluids, one is solid and another is liquid. Traditional heat transfer fluids are usually regarded as one of the primary causes of poor heat transfer equipment performance and increased energy expenses. Because of their ability to enhance the overall heat transfer coefficient, nanofluids have been considered as suitable substitutes for traditional fluids to solve this problem. Nanofluids can also enhance the quality of food by reducing processing time in the food industry. It has improved thermophysical characteristics including thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients when compared to base fluids like oil or water. The majority of the reviews concentrate on nanofluid thermophysical properties, both experimentally and theoretically.[11]

All unit actions involving heat transfer from a heating or cooling medium to a food product via a heat exchanger, such as refrigeration, freezing, thawing, pasteurization, sterilization, drying, and evaporation, may be done with nanofluids in the food business.

Preparation Methods

Two-Step Method

It is the most common approach for making nanofluids. Drying and powdering nanomaterials such as nanotubes, nanofibres, and other nano-particles is the first step. In the second-step, the nanopowders will be dispersed in fluids by ultrasonic agitation, homogenizing, intensive magnetic force agitation, high shear mixing, and ball milling. It is considered to be the most economical method, as nanosized particles are already produced at an industrial level.[12]

One-Step Method

A one-step physical vapour condensation method was developed for reducing the agglomeration of nanoparticles. It is similar to a two-step method. Here, agglomeration was minimised and the stability of fluids has increased by avoiding drying, storage, transportation, and nanoparticle dispersion. The dispersed nanoparticle is prepared uniformly in a one-step method so that the particles can be strongly suspended in oil or water (base fluids). Due to incomplete reactions, the residue of reactions was left in nanofluids, which are considered one of the disadvantages of this method.[12]

Applications of Nanofluids

Nanofluids have a wide range of applications in heat exchangers for processes like sterilization, distillation, concentration, pasteurization, and other heating and cooling processes in the food industry. It has recently been demonstrated that using nanofluids to optimize heat exchangers in food processing plants can be helpful not just from a technological standpoint but also when considering their impact on food quality. Adding Al_2O_3 (Aluminium oxide) nanoparticles to water and increasing the particle concentration resulted in a considerable increase in thermal conductivity, viscosity, and density but a significant decrease in specific heat capacity. In terms of heat transfer characteristics, one study indicated that using Al_2O_3/water at nanoparticle concentrations of 2% and 4% increased the HTC (Heat Transfer Coefficient) by 5.42 percent and 11.94 percent in the thermal processing of tomato juice, respectively.[13]

Benefits of Nanofluids

There will be changes in the size, shape, material, and volume fraction of nanoparticles because of the high absorption of solar energy. efficiently used in solar thermal applications. By changing the concentration of nanoparticles, the properties of the fluid can be changed. Heat transfer systems can be improved efficiently by suspending nanoparticles, which enhance thermal conductivity. Because of the very small suspended particles, the fluid's surface area and heat capacity will increase.

Limitations of Nanofluids

The limitations of nanofluids are poor long-term stability of a suspension, increased pressure drop and pumping power, lower specific heat, and a high cost of nanofluids.

Application of Nanotechnology in Food Preservation through Encapsulation Technique

Several facets of food science, including food preservation and safety, have been revolutionized by nanotechnology. Colors, tastes, antioxidants, enzymes, and anti-browning agents might all be delivered while edible nano-coatings on a range of food components act as a moisture and gas barrier. They may also be able to extend the shelf life of packaged meals once they have been opened. It is generally possible to slow down chemical breakdown processes by encapsulating functional components within droplets and altering the properties of the interfacial layer around them. The employment of films, coatings, coverings, or simple macro dispersion to encapsulate on a nanoscale scale is referred to as "nanoencapsulation." On the food or taste molecules or ingredients, the nanometer-scale encapsulating layer provides a protective layer. The active ingredient is frequently in the form of a molecule or a nanoparticle. Advanced physical and chemical properties and better encapsulation are all advantages of homogeneity. In the production of functional meals with increased functionality and stability, this strategy can be utilized to protect bioactive ingredients such as vitamins, antioxidants, proteins, and carbs.[14]

Nano Additive

Nanoadditives create a better dispersibility of water-insoluble added substances like tones, flavors, additives, and enhancements without utilizing any surfactant. These nano additives improve the flavor, dietary benefit, and retention of parts in the body because of their enormous surface area. The nutraceuticals of nanostructured bioactive compounds are interrupted by a nano-sized particle delivery system known as nanofood additives. To promote their characteristics, nanomaterials such as polar, non-polar, and amphiphilic are added to various foods and products' packaging, giving them various activities. Bioavailability components are created in order to improve the solubility of ingredients in food. The effect of nano-additives such as nano-PTFE (Polytetrafluoroethylene) and nano-CaCO3 (Calcium carbonate) on biological properties is thoroughly assessed using ball-disc wear and four-ball testers to the food-grade aluminum-based grease of lubricity, which will increase. After the inclusion of both nano-additives, the findings show that food-grade aluminum-based grease has outstanding biological characteristics.[15]

The dispersibility of water-insoluble additives (flavors, preservatives, nutrients, and colors) in food was improved by adding nano additives without using surfactants. Also, the nutritional value and absorption of components were improved due to their high surface area. Vitamins, antioxidants, colors, tastes, and preservatives are all examples of nano additives that are already accessible. In the food business, calcium, selenium, iron, silica, nanosized silver, and magnesium are being used as nano additives. Nano salt tastes better than regular salt when used in smaller amounts. Nanopolylysine protects oil from oxidation by filling the space between phytoglycogenoctenyl succinate nanoparticles.Loss of weight, Gas permeability has decreased, Thermodynamic stability and heat distortion temperature have both improved. Smoke emissions have been reduced, and flame retardancy has been increased. Chemical resistance has been improved. surface modification and functionality according to your needs, Electrical conductivity has been improved, Optical clarity as compared to filled polymers, A large processing window with a lot of options, Colorability has been improved. A significant focal point of current nanotechnology applications in food is the advancement of nanostructured (or nanotextured) food fixings and conveyance frameworks for supplements and enhancements. For this, an assortment of cycles is being used, including nano-emulsions, surfactant micelles, emulsion bilayers, and converse micelles. The ability to concentrate non-polar compounds is one of the prominent characteristics of micelles.[16] Nanostructured food fixes are being developed in the hopes of providing better taste, surface, and consistency. For instance, spreads, low-fat nanostructured mayonnaise, and frozen yoghurts are guaranteed to be as "velvety" as their whole-fat counterparts and, subsequently, offer a better choice to the buyer.[17]

Nanoemulsions

Nanoemulsions might be used to provide flavor compounds, coloring, antimicrobials, and nutraceuticals in the food business. Active ingredient nanoemulsion formulations can be utilized to create biodegradable coatings and packaging films that improve food quality, functionality, shelf life, and nutritional value. Most reviews were concerned with the manufacture of food-grade nanoemulsions utilizing low- and high-energy techniques as well as their physical characteristics, stability, and microstructure characterization.[18]

Coarse emulsions are also called microemulsions. They are thermodynamically metastable, and the dimensions of the particle are > 200 nm. They degrade over time as a result of a variety of destabilizing processes. Traditional emulsions are optically turbid because the droplet size is comparable to the wavelength, scattering light and giving the appearance of being opaque. Microemulsion droplets are 100 nm in diameter, and their thermal behavior is stable. However, even small changes in external factors such as composition and temperature have an impact on their stability. Because their free entropy is smaller than that of phase-separated components, microemulsions form spontaneously. Nanoemulsions have been produced for use in the purification of food, in bundling hardware, and in the bundling of food. A "regular" model is a nanomicelle-based item professed to contain normal glycerin. It eliminates pesticide buildups from products made from the soil, as well as the oil and soil from cutlery. Nanoemulsions stand out enough to be noticed in the food business because of their high clarity. These enable the addition of nanoemulsified bioactives and flavors to a drink without an adjustment to the item's appearance. Nanoemulsions are powerful against an assortment of food microorganisms, including gram-negative microscopic organisms. They can be utilized for the surface purification of food-handling plants and for the decrease of surface pollution on chicken skin. The development of Salmonella typhimurium provinces has been disposed of by treatment with nanoemulsion. Nanoemulsions can be used to confine functional chemicals and active elements like antioxidants and nutraceuticals.[19]

Composition of Nanoemulsions

The stability, formation, and functional features of a nanoemulsion are influenced by the components of the oil phase's viscosity, density, refractive index, interfacial tension, and phase behavior. The nanoemulsion in the aqueous phase is made up of a polar solvent and a cosolvent. Water is considered a common polar solvent, whereas proteins, carbohydrates, polyols, and alcohol are utilized as cosolvents. A stabilizer agent can be added to the nanoemulsion to avoid this. The stabilizers can produce a monolayer, multilayer, or solid particulate nanoemulsion depending on how they are distributed on the particle Emulsifiers, ripening retarders, weighing agents, and texture modifiers are some of the stabilizers employed. Emulsifiers are surface-active chemicals that are often utilized as stabilizers in the creation of nanoemulsions.[20]

The benefits of employing nanoemulsions in foods as bioactive chemical delivery vehicles have been demonstrated in a variety of in vitro and in vivo food challenge experiments. However, nanoemulsions of bioactive substances have only been employed as packaging materials or in commercial food items in a few cases. Food processing with nanoemulsions is a viable option. Temperature, oxidation, enzyme interactions, and pH fluctuations can all affect the functional components. Nanoemulsions have been employed in food items by companies like Nestle and Unilever, as well as a few start-ups. Nanocarriers provide coenzyme Q10 and alpha-lipoic acid in the Novasol sustain product. The micelle (30 nm) is entirely water-soluble and resilient to pH and temperature fluctuations. It is thought that the micelle is the best carrier system. Nanosized self-collected liquid structures connected with the nanosized vehicles are utilized as vehicles to focus on nutraceuticals. The vehicles have extended micelles with a size of 30 nm and can be utilized for "clear" refreshments without stage partition. They have instituted bracing nanovehicles. Their potential applications incorporate lycopene, beta-carotene, CoQ10, omega-3 unsaturated fats, phytosterols, and isoflavones.[21]

Appearance and Safety Issues in Food Nanotechnology

Even if a drug is GRAS (generally recognized as safe), extra research is required to assess the danger of its nano equivalents since their physicochemical characteristics differ considerably from those of macrostates. Furthermore, the nanomaterials' tiny size may raise the danger of bioaccumulation in bodily organs and tissues. When exposed to human lung cells, silica nanoparticles, for example, which are utilized as anti-caking agents and inserted into the cells, are cytotoxic. The rate of dissolution is influenced by particle surface shape, concentration, surface energy, aggregation, and adsorption. They studied the migration of copper and silver from nanocomposites and then observed that the proportion of nanofiller in the nanocomposites, rather than particle size, temperature, or contact length, was one of the most critical factors driving migration. Because each nanomaterial has its own unique properties, toxicity will most likely be determined. At this time, there is no convincing evidence that nanotechnology-derived foods are any safer or more harmful than their traditional counterparts. Despite the fact that international food safety agencies have yet to reach a general decision on the safety of nanofood containing nanomaterials, there is no evidence that ingested nanoparticles have affected human health. Various governments, including Australia, the European Union, the United States, and New Zealand, have created committees to monitor nanotechnology progress and take appropriate action if necessary. Nanoparticles are fabricated to represent food fixings and added substances to cover their undesirable preferences and flavors, shield the typified fixings from debasement, and further develop the scattering of water-insoluble food fixings.

Non-biodegradable materials, for example, plastics, have been utilized in ordinary food packaging. As of late, degradables, biodegradables, shrewd bundling (containing sensors and nanocomposites), or even palatable bundling (utilizing lipids, proteins, polysaccharides, and so on) have been available in food bundling. Biodegradable and consumable packaging have dealt with serious issues, including poor mechanical properties, low corrosion temperatures, mugginess, and gas porosity that forestall development. The novel properties of numerous nanomaterials can address these sorts of issues. Nanocomposites that contain different nanostructures, like inorganic stages and biodegradable polymers have been thought of Nanoclays are being created and refined. For clean reasons, food packaging must be made with idle materials, however, dynamic and brilliant materials have likewise been showcased as of late. Catalysts, anti-bacterials, and retentive materials not only increment the time spa of usability and further develop stockpiling conditions, but additionally make food dispersion a lot more straightforward. Manganese oxide, zinc oxide, and silver nanoparticles are instances of these dynamic particles with antimicrobial properties for bundling. Gold nanostructures, quantum dots (QD), carbon nanotubes, and other dynamic nanostructures have been or can be utilized as sensors of organisms or different tests for sanitation.[22]

Nanocoatings

The applications of nanocomposites and nanocoatings in food packaging are dependent on the properties of fixing in action. Nanoclay composites (typically montmorillonites) are used as flexible and reliable food packaging on account of their incredible hindrance attributes in bundling of grasp, cheddar, sweet shop, cereals, and bubble-wrapped food varieties. Things acquired by the expulsion covering process with the paperboard are valuable for juice, which comes from natural and dairy products, and the lager and carbonated drinks bottles are fabricated by co-expulsion processes. To give two examples, PET (Polyethylene Terephthalate) jugs containing nanocore and nylon beer bottles with nanoclays both exhibit improved obstructive properties. Antimicrobial, antifungal, cancer prevention agent, biocatalyst, responsiveness to outside upgrades, additional compounds that absorb unpleasant parts from food like ethylene, dampness, scent, etc. are just a few of the dynamic experts' capabilities. They are combined into a grid or covering to increase the food's quality and shelf life and are then delivered in a controlled manner. This method is much more effective than simply adding them directly to the food because they may react with other food components, which could impair their action or affect the food's sensory qualities. The coatings have been shown to be highly effective in holding carbon dioxide and blocking oxygen, and they can rival traditional dynamic sealants. Examples incorporate a nanocoating, which is a water-based, nanocomposite obstruction covering that furnishes an oxygen hindrance with a 1-2 micron covering for food bundling use, and a plasma curve statement of shapeless carbon inside PET jugs as a gas boundary.[23]

To give an obstruction to mass exchange, a slight object of palatable material will be set between the food parts, and through dampness, lipids, and obstruction of gas, these coatings will be filled. in food items Coatings are simply applied and framed, either by a fluid film expansion shaping arrangement or a mixture liquid. Parts of consumable coatings are partitioned into two classifications: water-solvent polysaccharides and lipids. Appropriate polysaccharides include cellulose subordinates, alginates, gelatins, and other polysaccharides. To generate edible films and coatings, a variety of lipid-chitosan formulations, like animal fat, have been used. Waxes, acylglycerols, and unsaturated fats are examples of appropriate lipids. Lipid films have excellent dampness-blocking capabilities and can be used as covering experts to give glitz to dessert shop products. Wax is frequently used to cover soil products in order to prevent breathing and dampness loss. Consumable coatings are now broadly utilized on a wide assortment of food varieties, counting natural products, vegetables, meats, chocolate, cheddar, confections, pastry kitchen items, and french fries. To slow the dissemination of oxygen, dirt (montmorillonite) has been added to gelatins. Also, nanocomposites organized by gelatin and montmorillonite have been utilized for improvements in their actual properties. A calculable expansion in the security of chitosan/layered nanocomposites was likewise created. Not with standing the absence of specific writing information, there is sufficient proof to lay out the positive effects of inorganic nanofillers on various products, including improved taste preservation, sugars, acids, surfaces and shading, increased strength during delivery and capacity, improved appearance, and reduced waste. The transporters of antimicrobials and added substances are utilized by nanoparticles. It may also be used to settle additional compounds and effectively manage their dispersion throughout the food and in different locations, such as the surface versus the majority of a food system. This control might be interesting for long-term food storage or imparting certain beneficial properties, such as taste, to a food framework. In this regard, the United States' Sono-Tek Corporation has developed an edible antibacterial nano coating that can be applied directly to bread shop items.

Nanolaminates

Food researchers can use nanotechnology to create unique nanolaminate films that are suitable for use in the food industry. A nanolaminate is made up of at least two layers of nanometer-scale materials that are physically or technologically connected to one another. The layer-by-layer testimony method, in which the accused surfaces are covered with interfacial films made of numerous nanolayers of diverse materials, is perhaps the most impressive strategy in nanolamination. Nanolaminates offer a few benefits for the readiness of consumable coatings and films over ordinary advancements and may consequently include various significant applications inside food. To create the distinct layers, a variety of adsorbing substances, such as ordinary polyelectrolytes, charged lipids, and colloidal particles, could be used. It would be feasible to fuse dynamic practical specialists, for example, antimicrobials, hostile to caramelizing specialists, cell reinforcements, catalysts, flavors, and colors, into the movies. These practical specialists would establish a realistic timeline for the usability and quality of covered food sources. The essential useful properties of overlaid films depend upon the attributes of the film-shaping materials utilized for their arrangement. Like nanocoating, these nanolaminated coatings could be made completely from palatable material fixings by utilizing straightforward handling activities, for example, plunging and washing. The organization, thickness, construction, and properties of the multifaceted cover conformed to the item could be controlled in various ways, remembering the changing of the sort of adsorbing substances for the plunging arrangements, the all-out number of plunging steps utilized, the request that the item be brought into the different plunging arrangements, the arrangement, and natural circumstances utilized, like dielectric constant, ionic strength, temperature, pH, and so on.

Nanolaminates with high interfacial constructions can be saved by means of a base-up, balanced thermodynamic affidavit approach named actual fume affidavit (Physical Vapour Deposition- PVD). On the other hand, two distinct metals are often used in PVD to achieve the correct thickness of the nanolaminate. For the production of two-layered (2D) planar nanocomposites, the most commonly used PVD technique is faltering. Because of the opposite cathode extremity, the anodic state of a substance results from the vaporous release or expulsion of material from a surface in faltering.

The source material, which is the objective, is placed on one side of the affidavit chamber, while the substrate surface, which will be used to shape the affidavit, is placed on the other.

To ionize the gas into plasma, a strong Direct Current (DC) voltage is supplied between the goal and the affidavit chamber's dividers. An Alternate Current (AC) voltage can also be used for ceramic target materials. The ionized gas will be definitely sped up by the voltage drop whenever it approaches the dull space sheath (a slender district near the target) and will thus hit the objective at a high speed. Particles, atoms, or clusters of molecules are relaxed and propelled out of the objective due to the high effect speed. These projectiles hit the substrate in a single direction, retaining their great energy.

Application of Nanotechnology in Bleaching Vegetable Oil

Vegetable oil is a staple food, hence the quality should be higher in a way that supports human's health. The four main techniques in the production of vegetable oil are neutralization (refining), degumming, bleaching and deodorization. Among these bleaching is a significant phase. It removes various impurities present in the oil, such as trace metals, gums, phosphatides, and fatty acid. Bleaching process mainly involves the use of adsorbent that can be used separately or in fusion.[24] As adsorbent, bleaching earth is used which looks like clay.[24] The study was conducted to assess the effectiveness of nanoparticles in bleaching earth.[25] For this sunflower, soybean and corn oil were taken and the bleaching earth was milled for 10 h. In between the degumming and bleaching process, analytical determination was made. To ensure this, 20 g of each vegetable oil was heated with 0.4g of bleaching earth in a rotary evaporator at 100 ºC under reduced pressure for 20 mins. Then, it is filtered through whatman filter paper (size no 1). The study has concluded that nanoparticles bleaching earth had better effective percentage (%) when compared to before milling.[25]

Regulations for the usage of Nanotechnology in Food Production

These days, there aren't any specific regulations on nanotechnology usage in foods. The Food and Drug Administration lists a number of products that are currently regulated as nanoparticles with particulate matter in the nano-size range, but has not focused on applied technology on preparedness. The Institute of Food Science and Technology recommended that when the nanoparticles are being used as food additives or preservatives, the standard E-numbers that are used for labeling the food additives should use the subscript "n".[26] The Government of Britain consented to this recommendation, stating that nanoparticle ingredients should be subjected to a complete safety measurement before they are used in food products.[27] The International Organization for Standardization (ISO) and American Society for Testing and Materials (ASTM) International are expected to develop nanotechnology principles in terms of nomenclature, characterization, terminology, safety, the environment, and health. The nanomaterials, when used as a primary ingredient, (such as nanoemulsions), fall under the Regulation (258/97) of "Novel Food." It is due to the fact that if any food product or its ingredient is new or its molecular structure is intentionally modified, they will be subjected to risk assessment prior to getting approval from the market.[28]

Risk Assessment of Nanomaterials in Food

An introductory outline has been developed to drop a dime on the risk analysis and management of nanomaterials. The increasing use of nanoparticles in various products results in the release of significant amounts of nanoparticles into the environment, which end up in landfills and aquatic areas.[5] So, certain factors that affect the ecological risks of nanoparticles and human health are studied. For the safety evaluation of nanomaterials, a forum series of certain articles was presented in toxicological sciences. Some techniques were explained through the body to assess the interaction of nanoparticles with biological systems for basic nanoparticle characterization. A very important aspect is the determination of nanoparticle solubility, its effects on health, and its biological fate. Certain factors influence dissolution, including aggregation, surface area, concentration, surface energy, and surface morphology.The risk assessment of nanoparticles and nanostructures revealed that the most likely routes of human exposure are the gastrointestinal tract, skin, and lungs.The "European Food Safety Authority" (EFSA) issued guidelines to assess the risk of nanomaterials, emphasizing the metallic safety on commercial products: (i) the state of the nanomaterial that is being produced,

(ii) the state of the nanomaterial used or the state in which it is present in food products, (iii) the state of the nanomaterial in toxicological studies, and (iv) the state of the nanomaterial in tissues and biological fluids.[29] The addition of nanostructured materials to drugs, food, and water causes the intestine to absorb them, and the circulatory system is invaded, but there hasn't been much research done on the invasion through this potential route. A legal foundation has been established to govern nanomaterials and their applications in the food industry. The Organization for Economic Co-operation and Development (OECD recommended the standard test guidelines be used for the hazard assessment of nanomaterials for chemical safety.

Conclusion

Multiple nanotechnology applications in the food sector and processing methods have developed in various countries, and some of them also include nano-based food preservatives or additives, smart delivery systems, medicine, and health care. People barely recognize and adopt the effects of nanotechnology after using it in their daily lives. The rising probability of nanotechnology makes it suitable for certain developing countries because they could probably capture the new markets for successive nanomaterials and their production systems. Research in the nanotechnology field has remarkably great potential for serving society through the food industries. In some food industries, the nano-biosensor can also be equipped for environmental pollution control. Inorganic nanoparticle production and microfluidic advancement have been equipped with the preparedness of dynamic sensors to readily detect disease-causing toxins or pathogens in food on the farm as well as in the final food product that is in the market. Because functionalized foods contain nutrient carriers and nanoparticle flavors, they emphasize food safety and quality. Finally, nanotechnology aids in the transformation of existing food processing systems to ensure product safety, promote a healthy diet, and improve nutritional quality.

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Conflict of Interest

There is no conflict of interest to declare.

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