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REVIEW ARTICLE

A Review of using Nanostructured Materials in Food Safety, Packaging and Storage

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Abstract: Food-grade Nano designed materials are largely utilized with a few methodologies for further developed food properties as far as quality and medical advantages. The food-grade nanostructured materials for the most part incorporate inorganic and natural materials, where the utilization of natural nanomaterials, like polysaccharides, proteins, lipids, and others, has been expanded for their profile based assets. Food-grade nanostructured materials might offer further developed food properties as far as surface, shading, flavor, supplement substance, rheology and others, which must be basically checked. The nanostructured materials are likewise used to foster bundling materials, in both essential and optional bundling, for custom fitted properties with diminished waste. Be that as it may, the food handling is estimated as far as movement properties, toxicological conduct of nanoparticle among bundle and food materials, as food handling is a main pressing issue in securing the bundled items for the duration of the existence cycle. Among accessible, polysaccharide-based nanostructured materials, for example, nanocellulose, nanochitosan, nanostarch, and so on, are widely utilized materials for tuned food properties.
Keywords: Food, nanotechnology, nanoparticle, Food Safety, Packaging

Introduction

In addition, researchers and industry stakeholders have already recognized the potential uses of nanotechnology effectively in every segment of the food industry such as agriculture, food processing and food packaging as a carrier of nutrients. In the case of food processing, the impact of nanomaterials is used in encapsulating flavor and odor compounds of the food for enhancing the sensory appeal, as an agent of improving the textural property of food and are also utilized as gelation and viscosifying agent. Moreover, in food packaging, nanomaterials are predominantly used as antimicrobial agents' sensors for detecting pathogen and gas, UV-protection agents, etc. Along with the above functions, it can also be used as active agents for delivering nutraceuticals with better stability and bioavailability.

Interestingly, various nanostructured materials are found to present naturally in some food materials such as milk contain casein micelles, plant or animal cells contain certain organelles (Livney, 2010; Holt et al., 2003; Iwanagaet al., 2007) and, further, the nanostructured materials are formulated as a result of regular food processing including grinding, homogenization, cooking, etc. (Gupta et al., 2016). Thus, nanoparticles have been developed unintentionally as a natural consequence which aids their influence on processing conditions. In this context, it is important to determine the potential sources of various nanoscale materials in food or in other natural sources. Besides, the designed nanoscale materials are also developed intentionally to incorporate into the food for tailoring the inherent property, which makes it functional food for consumer benefits. However, the restriction of usage ofthese materials is mainly due to safety concerns after consuming the food. Moreover, the mechanism of their action is not completely discovered, and sometimes the added nanoparticles into the food or packaging material may leach out and transfer to another side of packaging material. These designed nanostructured materials are basically nanoparticles where the size, shape, composition, and interfacial properties are developed to achieve functional attributes. Moreover, the aim of developing these nanoscale materials is to utilize as a delivering agent for nutraceuticals, colors, flavors, preservatives. In addition, the potential renewable origin-based bio-nanostructured materials are also able to improve the texture, appearance, and stability of the food.

Nanoemulsions

The particle size of nanoemulsion is in the range of 20 to 200 nm with suitable thermodynamic stability (Delmas et al., 2011). The emulsion is generally formed in the presence of surfactant, where two immiscible liquids develop transparent emulsions, where high- and low-energy methods are generally used to produce these nanoemulsions (Yang et al., 2012). The common methods used for low energy is membrane emulsification, spontaneous emulsification, solvent substitution, reverse emulsion, and reverse phase. In the case of high energy, mechanical methods are used such as colloid mills, high-pressure, and ultrasound homogenizer (Date et al., 2010, Jaiswal et al., 2015). In addition, the industry prefers high-energy methods due to the formation of adequate, controlled size, and high-quality emulsions. Further, nanoemulsions are mainly utilized for the development of functional drinks where vitamins, minerals, and other bio-actives are supplied, which also helps in controlling the functional compounds in the developed functional drinks (Rao and McClements, 2012; Lane et al., 2014). The release of functional compounds from nanoemulsion also depends on several factors including heat, pH, sound frequencies, and other stimulants. Further, the antimicrobial activity of nanoemulsion is helpful for decontaminating the food equipment, packaging materials.

Nanoliposomes

Another form of lipid nanostructured material is liposome which is also used to make functional foods. It is a colloidal particle of lipid molecules, which accumulates in the form of organized bilayer membranes after reacting with water. Liposomes have the capacity to encapsulate both hydrophilic and hydrophobic substances. It can encapsulate hydrophilic active compounds inside the membrane and hydrophobic substances between the membranes. However, nanoliposomes are less used in the food industry due to its unstable structure.

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Protein Nanoparticles

Protein nanoparticles are a good candidate for releasing drugs and various beneficial components into the food. It has plenty of advantages including enhancement of drug release, reduction of toxicity, and improvement of bioavailability and also provides better formulation opportunities. These particles are also able to show better action at the minimum dose and help to decrease the drug resistance in the body. However, the most common protein nanoparticle is casein micelles in bovine milk, which is the small clusters of casein molecule and calcium phosphate ions (Livney, 2010; Holt et al., 2003). Further, this nano structured material, casein micelle is naturally present in milk as a delivering agent of nutrients like protein and minerals. More recently, after observing the properties of this nanomaterial, much interest has been raised for developing a variety of protein nanostructured material for food application. Although a little concern for potential toxicity exists for long-term consumption of protein nanoparticles. In addition, other protein nanoparticles used in food are whey, zein, gliadin, gelatine, and soy protein particles, where their size varies from few nanometers to hundreds of nanometers. Similar to lipid nanoparticles, they are also able to encapsulate, protect, deliver bioactive compounds including color, flavor, preservative, vitamins, minerals and nutraceuticals.

Carbohydrate Nanoparticles

Carbohydrates are the natural biopolymer, which is extracted from natural resource (i.e., animal and plant) including agricultural waste. Some of the common polysaccharides are cellulose, starch, chitosan, alginate, pectin, and xanthan. Based on their chemical nature, polysaccharides can be digestible and indigestible inside the human body. However, nanoparticles can be developed from these biopolymers by cleaving the natural glyosidic linkage presents between the monomers. chains, various biopolymers, including cellulose, starch, and chitosan, are fabricated. Further, breaking down of the polymer chain is done in two different ways using chemical and mechanical processes. The chemical process deals with the application of temperature, changing in pH, application of enzyme, acid, and ionic liquids, whereas the mechanical process includes ultrasonication, ball milling, homogenization, etc.

Inorganic Food-Grade Nanostructured Materials

The main concern in food processing is to protect against foodbome illnesses, which causes a significant problem in public health worldwide. One of the possible ways to prevent foodborne diseases occurring from food through the development of active food packaging. Furthermore, the foodbome diseases can be prevented by the antimicrobial agents, releasing from the active food packaging material. In general, active packaging is developed by the addition of functional bioactive compounds into the packaging material itself and by releasing these compounds from the packaging material into the food. In this context, inorganic food-grade nanostructured materials can also aid the beneficial effects through releasing the biocide into the food directly or to the space around the food.

Nanoparticles In Food Safety and Preservation

As mentioned earlier, the rapidly growing nanotechnology has a wide impact on the food sector, where the most interesting outcome of this technology is nanomaterials and their uses in the food system. However, the advancement of nanotechnology in the food industry needs more concerned research before commercializing food products with nanoparticles for the consume since it may cause unhealthy attributes. Further, the food industry will only accept the novel nanomaterials when the issues related to safety are addressed (Ghosh, 2018; te Kulve et al., 2013). Various researches are still going on for establishing the permissible limit of using nanomaterials in food for consumption. will be discussed in the later sections. Interestingly, one guidance document has provided relating to the handling of risk associated with certain food related nanotechnology. They discussed the engineered nanomaterials and their uses in food additives, enzymes, flavorings, food contact materials, novel foods, food supplements, feed additives, pesticides, etc. Further, the USFDA has made the draft guidance for the industrial use of nanomaterials in animal feed (Commissioner, 2019). However, more research is required to determine the actual impact of nanomaterials in food and on human health to ensure public safety and the public communication for the safe use of such materials along with the food (Handy and Shaw, 2007; Aschberger et al., 2015). Though, no such worldwide protocols for testing the toxicity for the nanostructured materials are available; however, the protocols are still under development stage by some of the organizations such as the International Alliance for Nano Environment, Human Health and Safety Harmonization (Maynard et al., 2006) and the US National Research Council (Council, 2007).

Application of Nanostructured Materials in Food Safety, Packaging and Storage

As mentioned earlier, the bio-based nanostructured materials are extensively used in everyday life, where nanotechnology makes life easier to benefit the entire society. Bio-based nanostructured materials are deliberated as a promising candidate to supply tailor-made food properties with respect to preservation, protection, and safety throughout the product lifecycle. The nanostructured materials are significantly used to modify the available technologies for food protection particularly in the area of active packaging, smart packaging, edible nanocoating, etc. where the nanomaterials play a remarkable role in various emerging sectors. The materials are very essential in many areas for their tunable properties in terms of biodegradability, biocompatibility, nontoxicity, dimensional stability, structure, surface properties, etc. Further, the effective nanomaterials in terms of functionality can be formulated using various functionalizers, plasticizers, cross-linkers, etc.

Edible Food Packaging

Edible food packaging is an emerging class of packaging that is produced worldwide which is eatable in nature and available in different forms. The two categories of edible food packaging generally include edible films and coatings. Edible films are obtained as a thin layer of edible materials which are applied on food products or can be used as sandwich materials. Whereas, edible coatings are considered as a postharvest technique where the eatable materials are applied to food products via dipping or spraying.

However, modernization in the world shows a great need for natural products. The postharvest management systems, such as drying, freezing, and addition of preservatives, generally change the food quality. In this regard, the world is in a need of natural, fresh, and ready to eat products, which can be obtained through edible food packaging. Tire materials for edible food packaging generally involve polysaccharides, proteins, fats, or lipids. However, among available polysaccharide materials, cellulose, chitosan, and starch are extensively used materials for edible packaging.

Edible Films

Similarly, cellulose nanofibers are also utilized with mango puree as nanocomposite-based edible films, where cellulose nanofibers are considered very effective for obtaining tunable packaging properties (Azeredo et al., 2009). Further, the cotton linter cellulose nanofibril-reinforced sodium carboxymethyl cellulose improves the water barrier and tensile properties of carboxymethyl cellulose (Oun and Rhim, 2015). The edible films with cellulose nanofibril incorporated carboxymethyl cellulose form a smooth and flexible edible film with improved properties (Oun and Rhim, 2015). Alginate-acerola puree incorporated cellulose whisker can also be used as edible films, where the inclusion of cellulose whiskers helps to improve the tensile strength, elastic modulus,

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and water vapor barrier properties (Azeredo et al.,2012). The edible films based on pectin and crystalline nanocellulose can provide improved mechanical properties of the biocomposite films (Chaichi et al., 2017). The addition of pectin with crystalline nanocellulose has the capability of offering improved water barrier properties. The edible films based on pectin with 5% nanocrystalline cellulose can improve the tensile strength up to 84% (Chaichi et al., 2017). The development of polyelectrolyte films utilizing chitosan, olive oil incorporating cellulose nanocrystals is also available as edible films with significant properties (Pereda et al., 2014).

Conclusion

The available bio-based nanomaterials are considered as promising agents in the food sector especially in edible food packaging (edible nanocoatings and edible films), intelligent packaging, active packaging, and food functionalization. Both the organic and inorganic food-grade nanomaterials are utilized for the development of effective packaging materials. The bio-based nanostructured mediated packaging materials also combine with inorganic nanomaterials for improved effectiveness in terms of packaging properties and activity such as active or smart packaging. The inorganic food-grade nanomaterials play a significant role in the fabrication of smart or intelligent packaging materials. Considerably, the bio-based materials are extensively used for the preparation of biodegradable packaging materials for reduced plastic-based waste and associated carbon footprint. Further, the safety of bionanostructured materials can be measured following available rules and regulations such as European Union legislation, HACCP, GHP, GMP, etc. The migration and toxicological behavior of packaging materials play a very crucial role in selecting the particular packaging materials for specific food items. In this way, the various available bionanostructured materials are used for food preservation considering the available safety rules.

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CONFLICTS OF INTEREST

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