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Nanotechnology approach in food science: A review

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Abstract
Nanotechnology is the ability to create and manipulate atoms and molecules on the smallest of scales. The intervention of nanotechnology has brought a revolutionary change in food sector due to its capability of reformulating metals into new nanosized particles, with dimension less than 100 nm in size. Food quality monitoring using biosensors- intelligent, active and smart food packaging systems; nanoemulsions and nanoencapsulation of bioactive food compounds are some examples of emerging applications of nanotechnology in the food sector. Nanotechnologies are set to impact on the food industry at all stages of production from primary production at farming level, due to advances in pesticide efficacy and delivery (novel formulations and better crop adherence), to processing where emulsion creation and encapsulation have progressed to the nanoscale. The aim of this review is to provide a comprehensive analysis of recent developments in nanotechnology and their approach in food and bioprocessing industry. It also outlines the safety issues that may arise due to the incorporation of nanoparticles into the food products and packaging materials.

Keywords: nanotechnology, biosensors, nanoemulsions, nanoencapsulation, packaging, bioprocessing

Introduction
Nanotechonlogy is a newly emerging technique, which involves the characterization, fabrication, and manipulation of structures, devices or materials that have at least one dimension having 1-100 nm in lengthc [1]. This technology deals with nanomaterials and nanosystems commonly smaller than 100 nanometers. Nanomaterials are defined as materials with any external dimension on the nanoscale, and are clustered into three classes, namely nanoparticles, nanofibers and nanoplates [2]. It is observed that nanomaterials have unique properties unlike their macroscale counterparts due to the high surface to volume ratio and other novel physiochemical properties like color, solubility, strength, diffusivity, toxicity, magnetic, optical, thermodynamic, etc. [3]. Nanosciences and nanotechnologies connect diverse disciplines, among others physics, chemistry, life sciences, medicine, cognitive sciences, engineering, information and communication technologies, and therefore represent a real convergence among up-to-now distant fields of knowledge. Among these, the impact of nanoscience in many fields connected to health and well-being is nowadays very strong and the applications of nanotechnologies are expected to bring large benefits to the food and nutrition sector. Nanotechnologies may provide new ways and tools for controlling properties and structuring foods, introducing new features and creating added value [4].
Nanotechnologies are set to impact on the food industry at all stages of production from primary production at farming level, due to advances in pesticide efficacy and delivery (novel formulations and better crop adherence), to processing where emulsion creation and encapsulation have progressed to the nanoscale [5]. Nanotechnology is contributing to the development of innovative packaging materials that can improve the safety and shelf life of products by providing barrier materials or detect foodborne pathogens [6]. Some food materials packaging are equipped with nano sensors is designed to track either the internal or the external conditions of the food products, pellets and containers throughout the supply chain. Such packaging can monitor temperature or humidity over time and then provide relevant information on these conditions [7]. Nanotechnology also provides a vast range of opportunities for the development of new products and applications in food system. Functional foods, nutraceuticals, bioactives, pharma foods, etc. are very recent example of it. Nano-particles of Titanium dioxide, Silver, Zinc, Zinc Oxide, Silicon dioxide, Platinum, Gold are use vastly in food industry in different forms [8].
The objective of this review is to provide a comprehensive analysis of recent developments in nanotechnology and their approach in food and bioprocessing industry.

Application of nanotechnology in food processing
The food market demands technologies, which are essential to keep market leadership in the food processing industry to produce fresh authentic, convenient and flavourful food products and nanotechnology is the answer to it [7]. Food processing methods that involve the nanomaterials in their contents include incorporation of nutraceuticals, gelation and viscosifying agents, nutrient delivery, mineral and vitamin fortification and nanoencapsulation of flavours [9].

Nutraceuticals

Nutraceutical compounds such as bioactive proteins are used in functional foods to impart a health benefit to consumers in addition to the nutrition that the food itself offers. Nanomaterials can be used as bioactives in functional foods [10]. Examples of bioactive include beta-carotene from carrots, lycopene from tomato, beta-glucan from oats, omega-3 acid from salmon oil, conjugated linoleic acid from cheese, lactobacillus from yogurt, and isoflavones from soybeans.[11] Reducing the particle size of bioactives may improve the availability, delivery properties and solubility of the bioactives and thus their biological activity. The biological activity of a substance depends on its ability to be transferred across intestinal membranes into the blood [12, 13]. Some nutraceuticals incorporated in the carriers include lycopene, beta-carotenes and phytosterols are used in healthy foods to prevent the accumulation of cholesterol [14].

The prospect of the production of nutraceuticals at the nanoscale, which will have increased stability throughout the processing chain, will be of significant interest to food processors trying to maximise nutrient content and hence will ultimately be of benefit to consumers [5].

Nanoencapsulation

Nanoencapsulation is defined as the technology of packaging of nanoparticles of solid, liquid or gas, also known as the core or active, within a secondary material, named as a matrix or shell, to form nanocapsules [15]. The core contains the active ingredient (e.g., drugs, perfumes, biocides, vitamins, etc.) while the shell isolates and protects the core from the surrounding environment. This protection can be permanent or temporal, in which case the core is generally released by diffusion or in response to a trigger, such as shear, pH or enzyme action, thus enabling their controlled and timed delivery to a targeted site [16, 17].

Nanoencapsulations mask odours or tastes, control interactions of active ingredients with the food matrix, control the release of the active agents, ensure availability at a target time and specific rate, and protect them from moisture, heat, chemical, or biological degradation during processing, storage and utilization and also exhibit compatibility with other compounds in the system [18, 19]. The protection of bioactive compounds, such as vitamins, antioxidants, proteins and carbohydrates may be achieved using nanoencapsulation for the production of functional foods with enhanced functionality and stability [20].

Nanoemulsions

When one of two immiscible liquid phases is dispersed as droplets, the resulting mixture is referred to as an emulsion. Nanoemulsions consist of oil droplets in the nano-ranged size, between 10 and 100 nm dispersed within an aqueous continuous phase, with each oil droplet surrounded by surfactant molecules [21].

Nanoemulsions can protect flavour compounds from manufacturing conditions and throughout the beverage's shelf-life. It is claimed that nanoemulsions can capture the flavour and protect it from temperature, oxidation, enzymatic reactions and hydrolysis and are thermodynamically stable at a wide range of pH values [7]. Nanoemulsions have recently received a lot of attention from the food industry due to their high clarity. These enable the addition of nanoemulsified bioactives and flavours to a beverage without a change in product appearance. Nanoemulsions are effective against a variety of food pathogens, including Gram-negative bacteria. They can be used for surface decontamination of food processing plants and for reduction of surface contamination of chicken skin. The growth of Salmonella typhimurium colonies has been eliminated by treatment with nanoemulsion. The nanoemulsions showed great promise for use in beverage and other applications [22].

Application of nanotechnology in food packaging

The purpose of food packaging is to increase food shelf life by avoiding spoilage, bacteria or the loss of food nutrient. Nanotechnology offers higher hopes in food packaging by promising longer shelf life, safer packaging, better traceability of food products and healthier food [23, 24]. In recent years, there is more concern about research and innovation in food packaging materials ranging from films, carbon nanotubes, to waxy nano-coatings for some foods. The use of nanoparticles might help in production of new food packaging materials with improved mechanical, barrier and antimicrobial properties to increase shelf life [24, 25]. Beside antimicrobial characteristics, nanoparticles can be used as vehicle to deliver antioxidants, enzymes, flavors, anti-browning agents and other materials to extend shelf life, even after opening [26, 27]. A variety of nanomaterials such as silver nanoparticle, titanium nitride nanoparticle, and nano titanium dioxide, nano-zince oxide, and nanoclay are introduced as functional additives to food packaging [28]. Nanotechnology enabled food packaging can be divided into three main categories [1, 29].

Improved packaging

The use of nanoparticles in the polymer chain improves the packaging properties of polymer such as gas barrier properties, polymer flexibility as well as temperature and humidity resistance [1, 29].

Active packaging

The use of nanomaterials in packaging allows packages to interact with food and the environment and also play a dynamic role in food preservation [29]. Several nanomaterils like nanocopper oxide, nanosilver, nanotitanium dioxide, nanomagnesium oxide and carbon nanotubes can provide antimicrobial properties. Presently, the use of silver nanoparticles as antibacterial agents in food packaging is increasing [1].

Intelligent/smart packaging

The use of nano-devices in the polymer matrix can monitor the condition of packaged food. This packaging is designed for sensing biochemical or microbial changes in the food. It can detect specific pathogen developing in the food or specific gases from food spoiling. Some smart packaging has been developed to be used as a tracing device for food safety or to avoid counterfeit [1, 7, 29, 30, 31].

Nanotechnology and Safety Issues

Nanotechnology has brought revolution in food industry as it

has several applications in all areas of food science, from agriculture to food processing including packaging [32].

Although the hazards and risks of nano-technology are not known but can be assumed that like any other technology this may also have associated hazards and risks. Environmentalists are afraid that nano-technology may produce contaminants, which because of their nano-size, may pose to be ultra-hazardous [33]. Even if these particles are not harmful, their interaction with products may be harmful [34]. The interaction of nanoparticles with living cells is not yet understood completely [11]. Consumers are exposed to nanomaterials by consumption of food and beverages containing these extremely small particles of large reactive surface area of unknown safety [35]. The small size of these nanomaterials may increase the risk for bioaccumulation within body organs and tissues [36]. The nanoparticles are more reactive, more mobile, and likely to be more toxic. The ingredients in these nanoparticles must undergo a full safety assessment by the relevant scientific advisory association before these are permitted to be used in food industry [32].

Conclusion

Nanotechnology is emerging as a rapidly growing field with its wide application in food science from primary production of food at farming level to food processing and their packaging. The intervention of nanotechnology has brought a number of changes in food industry such as it significantly increased the shelf life of food products with better management of their spoilage. This advancement will also overcome the existing challenges that are associated with food and bioprocessing industry. With intelligent innovations it will positively affects the food quality, safety and security of food to meet the consumer demands. However, more research is required regarding the migration behaviour of nanoparticles from the packaging materials to food and their potential health implications. The nanoparticles must undergo a specific safety assessment before they are incorporated into the food products and the packaging materials.

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