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# Nanotechnology in food industry – A review

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**Abstract:** Nanotechnology is the technology of manipulation of matter at the nanometer scale. Materials of nanostructure may possess unique physical and chemical characteristics. Nanotechnology enables the development of new products in various fields. It also paves a way for the improvement of existing conventional products with better efficacy, solubilityand bioavailability. Nanotechnology has been applied in various sectors including electronics, medicine, diagnostics, military, food industry etc. The application of nanotechnology in food has gained great importance in the recent years in view of its potential in the development of novel and healthier food. Food nanotechnology opens up new possibilities for development of innovative food products. Application of nanotechnology in food includes improvement of packaging, processing, nano-additives, cleaning and sensors for detection of contaminants. This paper deals with the applications of nanotechnology in food industry.
**Keyword**: Nanotechnology, Food industry, Food packaging, Food processing, Sensor.

## Introduction

Nano-sized biomaterials, nanoparticles in specific, have unique physic-chemical properties such as ultra-small and highly controllable size, large surface area to mass ratio, high reactivity, and functionalizable structure[1]. Nanotechnology is defined as a knowledge application for matter's manipulation and control of matter at nanometric scale (1-100 nm). Nanostructures may present unique physical and chemical characteristics, demonstrating high reactivity and solubility, and improved stability than the original compound. Nanotechnology allows the development of new products and also the possibility of reworking on conventional materials in view of better efficacy[2]. According to National science Foundation and NNI, Nanotechnology is the ability to understand, control and manipulate matter at the level of individual atoms and molecules[3]. Recent advances in nanosciences and nanotechnologies have led to the emergence of huge interest in the control, manipulation and application of materials at the nano-scale.

Food nanotechnology is an area of rising attention and unties new possibilities for the food industry[4]. The new materials, products and applications derived from nanotechnologies are anticipated to bring lots of improvements to the food and related sectors, impacting agriculture and food production, food processing, packaging, distribution, storage and developments of innovative products[4]. The main driving principle behind these developments seems to be aimed at enhancing uptake and bioavailability of nano-sized nutrients and supplements, and improving taste, consistency, stability and texture of food products[5,6]. Nanotechnology can be used in all the phases of the food production chain (Table- 1), from the agricultural production to the industrial processing and finally the packaging of foods material. Nanoparticles can also be used in food to enhance the nutritional aspects, by means of nanosupplements and nano-delivery systems for bioactive compounds[7].

## Food packaging:

Improvements in the physical or chemical characteristics of packaging materials, such as strength, barrier quality, antimicrobial activity, and resistance to temperature, are being developed using nano-composite materials[8]. Other applications of nanotechnology in packaging include sensors that can detect food spoilage, nanoclay-nylon coatings and silicon oxide barriers forglass bottles that impede gas diffusion, metallized films, antimicrobials incorporated in packaging, smarter bar codes, and improved pigments, inks, and adhesives. Nano-silver is finding increasing applications as an antimicrobial, anti-odorant, and a health supplement. Although the current use of nano-silver relates mainly to health-food and packaging applications, its use as an additive in antibacterial[9].

The conventional bulky forms of silica and titanium dioxide are permitted food additives (SiO2, E551, and TiO2, E171). Nano-silica is known for its use in food contact surfaces, foodpackaging, inpowdered soups as they are free flowing and also in the clearing of beers and wines[10]. Nano-titanium dioxide are being used in a number of products including paints, coatings and foodstuffs[4]. Nano-selenium is used as an additive in tea product[4]. Surface functionalized nanomaterials that containcertain added functionalities are also being studied. These are currently mainly used in food packaging applications (e.g. organically-modified nanoclays), to bind with polymer matrix to offer mechanical strength or a barrier against movement of gases, volatile components (such asflavours) or moisture[6]. Incorporation of clay nanoparticles into an ethylene-vinyl alcohol copolymer and into a polylactic acid biopolymer was found to improve the oxygen barrier properties which may help in extend shelf life of food products[11].

Polymer-silicate nanocomposites have been reported to have improved gas barrier properties, physical strength, and thermal stability[12, 13, 14]. Nano-coatings (e.g. of TiO2) for photocatalytic sterilisation of surfaces and water, nano(bio)sensors for food safety, and nano-barcodes for food authenticity[5]are also emerging applications. Water treatment, filtration, and desalination using nanotechnologies offerextensive benefits in terms of safe use/ re-use of water. Coating of starch colloids filled with antimicrobial substance enables protection of the food by killing the microorganisms if grown on the packaged food as they penetrate the starch releasing the antimicrobial agent to act on them[15].

## Food processing:

Some food processing techniques utilize enzymes to modify food components to improve their flavor, nutritional quality or other characteristics. Nanoparticles are used as a source to immobilize these enzymes which may aid in the dispersion throughout the food matrices and enhance their activity. Nano-silicon dioxide particles with reactive aldehyde groups which covalently bind to a porcine triacylglycerol lipase effectively hydrolyze olive oil. This helps in improving the stability, adaptability, and reusability[16]. Nanocharcoal® adsorbent is a nanoparticle product used for the decoloration of food products[17].

## Nano-sized supplements and nutraceuticals:

These have been developed to enhance nutrition, andto improve health and well-being. Nano- sized supplement relates to processing of foodstuffs to develop nano- scale structures and stable emulsions/mixtures to improve the consistency, taste and texture attributes of the food. Nano-textured foodstuffs enable reduction of fat usage thereby contributing to healthier food. An example of product would be a ice cream, mayonnaise or spread which is nano-textured, which could low in fat but as "creamy". These products would render 'healthy' but still tasty food products[4]. Development of micronized starch, cellulose, wheat and rice flour, and spices for food applications are currently on going[18, 19].

## Nano-sized additives in food:

The main benefits that could be attributed to the nano – sized additives would be better dispersibility of water insoluble additives (e.g. colours, flavours, preservatives, supplements) in food products without the use of additional surfactants/emulsifiers[4]. This is believed to enhance the taste and flavour due to the larger surface areas of the nano-sized additives, enhanced absorption and bioavailability in the body. Currently available products are vitamins,antioxidants, colours, flavours, and preservatives. Nano-sized carrier systems for nutrients and supplements are also developed for use in food products. These are based on nanoencapsulation of the active in the form of liposomes, micelles, or protein based carriers. These nano-carrier systems are used to mask the undesirable taste of certain additives and supplements, or to protect some them from degradation during processing[4]. Enhanced bioavailability, antimicrobial activity are the added claims of the nano-encapsulated nutrients and supplements.

Inorganic nano-sized additives like silver, iron, calcium, magnesium, selenium and silica are also finding applications in food area. It is claimed that these additives improve the taste and flavours as a result of larger surface areas. Nano-salt enables consumer to enjoy the salt better even when used at a lower levels[4]. A food-grade polypeptide,ε-Polylysine is used to protect oil from oxidation. These Polylysine nanoparticles are much smaller than phytoglycogen octenyl succinate nanoparticles, allowing them to fill in the gaps between phytoglycogen octenyl succinate nanoparticles[20].

## Nanoencapsulation:

Nanoencapsulation is the technology of enclosing substances in miniature by using nanocomposite, nanoemulsification, and nanoestructuration techniques. This allows the controlled release of the core active molecule[21]. The protection of compounds like vitamins, antioxidants, proteins, and lipids as well as carbohydrates may be attained by use of Octenyl succinic anhydride-ε-polylysine. This acts as bifunctional molecules as either surfactants or emulsifiers in the encapsulation of nutraceuticals or drugs or as antimicrobial agents[22.] Hydrophobically modified starch formed micelles encapsulating the active ingredient of turmeric, curcumin[23]. The performance of antioxidants are enhanced by Lipid-based nanoencapsulation systems thereby by improving their solubility, bioavailability, stability, and preventing unwanted interactions with other food components. Nanoliposomes, nanocochleates, and archaeosomes are efficient lipid-based nanoencapsulation systems that can be used for the protection and delivery of foods and nutraceuticals. The application of nanoliposomes as carrier vehicles of nutrients, nutraceuticals, enzymes, food additives, and food antimicrobials was reported[24, 25]. Coenzyme Q10 nanoliposomes were produced with the desired encapsulation quality and stability[26]. Colloidosomes are minute capsules made of particles one tenth the size of a human cell and assemble themselves into a hollow shell. Molecules of any substance can be placed inside this shell. Molecules of any substance can be placed inside this shell[21].

Nanocochleates are purified soy based phospholipid containing at least about 75% by weight of lipid (phosphotidyl serine, dioleoylphosphatidylserine, phosphatidic acid, phosphatidylinositol, phosphatidyl glycerol and/or a mixture of one or more). Nanocochleates are nanocoiled to wrap the micronutrients and thereby stabilize and protect an them and have the potential to increase the nutritional value of processed foods[27, 28]. Nanoencapsulation of beneficial microorganisms, probiotics is advantageousas targeted and site specific delivery to the desired region of the gastro-intestinal tract can be achieved. These nanoencapsulated designer bacterial preparations can be used in vaccine preparation as well to improve the immune response[29]. Nanoemulsions improves the health benefits of curcumin[30].

## Cleaning and disinfection:

Titanium dioxide is used as a disinfecting agent as it generates reactive oxygen species in the presence of UV light that cause degradation of pathogenic microorganisms. However, this efficiency of the titanium dioxide is impaired as most of the excited electrons recombine and do not produce radicals. Deposition of silver on nanoparticles of titanium dioxide improves the antibacterial activity of titanium dioxide against *E. coli*[31] whereas when combined with carbon nanotubes it exhibits enhanced activity against *Bacillus cereus* spores[32]. Silver-doped titanium dioxide nanoparticles also inactivated *B. cereus* spores on aluminum and polyester surfaces[33] and destroyed airborne bacteria and molds when incorporated into an air filter[34]. Nanoparticles of silver when stabilized with SDS or PVP effectively inhibitsthe pathogenic bacteria like*E. coli* and *Staphylococcus aureus*[35]. Surfaces of refrigerators and storage containers are coated with silver nanoparticles to prevent growth of pathogens and spoilage bacteria[8].

## Sensors:

Biosensor technology have been extensively used to detect gases in packaged foods to evaluate the integrity of the packaging material, release of compounds during spoilage of food items and the presence of pathogens or toxins in foods[36,37,38]. Methods for identification of bacteria, viruses, toxins or other organic compounds have been developed based on nanotechnological methods and devices[8]. Immunosensing of Staphylococcus enterotoxin B (SEB) in milk was achieved using poly(dimethylsiloxane) (PDMS) chips with reinforced, supported, fluid bilayer membranes. Antibodies to SEB were attached to the bilayer membrane in PDMS channels to form a biosensor with a detection limit of 0.5 ng/mL[39].

A Universal G-liposomal nanovesicles based immune-magnetic bead sandwich assay was developed to simultaneously detect *E. coli* O157:H7, Salmonella spp., and *Listeria monocytogenes*in food[40]. An electrochemical glucose biosensor, with detection and quantification limits of 0.035 and 0.107 mM, respectively, was nanofabricated by layer-by-layer selfassembly of polyelectrolytes on an electrode platform. Multi-walled carbon nanotubes dispersed in the perfluorosulfonated polymer, Nafion, were deposited on a glassy carbon electrode followed by adsorption of a chitosan derivative as a polycation and glucose oxidase as a biorecognition element. Glucose in solution was detected by changes in current[41]. Allergic protein of peanut in chocolate[42] and other pathogenic microorganisms[43] are detected by liposome nanovesicles.

## Conclusion

Nanotechnology has many key and important applications in the food industry in terms of food safety and quality control. Nanotechnology has the potential to improve the nutritional value of food, to generate new novel food products, new safe food packaging for extended storage. However, this new technology also raises concern about risk assessment. It is critical to develop reliable tools to detect the presence of nanoparticles and assesses the possible adverse effects due to the application of nanoparticles.

**Table 1: Application of nanoparticles in food industry[7]**

| | | |
|---|---|---|
| **production tool**<br><br>nanosieves<br>nanosensors | | *removal of pathogens or contaminants*<br>detection of micro-organisms, food deterioration |
| **Inert nanoparticles**<br>water purification/soil cleaning<br>food storage<br>food packaging materials<br>food supplements | $Al_2O_3$, La, nano-Fe<br>Ag<br>Ag, $SiO_2$, Mg, ZnO<br>colloidal metals | oxidation of contaminants<br>anti-bacterial<br>prevention of food deterioration<br>enhanced uptake |
| **'nano delivery systems'**<br>nanocapsules<br>nanocapsules<br>nanocapsules | pesticides<br>bioactive<br>compound<br>nutrients | increased efficacy and water solubility,<br>local and controlled release<br>local and controlled release,<br>increased absorption and bioavailability<br>local and controlled release,<br>increased absorption |

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