Recent Trends in Nanotechnology Applications in Foods

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Abstract

Nanotechnology is having an impact on several aspects of food science, from how food is grown to how it is packaged. Companies are developing nanomaterial that will make a difference not only in the taste of food but also in food safety and the health benefits that food delivers. Nano science and nanotechnology are new frontiers of this century and food nanotechnology is an emerging technology and opens up a whole universe of new possibilities for the food industry. In the former field, better food quality and safety evaluation can be achieved by using nanotechnology. In the latter, food processing can be largely improved by applying nanotechnologies such as Nano liposomes, Nano emulsion, Nano fibers, Nano encapsulation, Nano coating. Nano-sized Ingredients/ Additives such as Nano-salt, WOW Mayonnaise and to produce fresh authentic, convenient and flavorful food products. In this review, we clearly show the latest development and applications of nanotechnology, especially in food processing industries. Nanotechnology will replace many fields with tremendous application in the area of food processing and packaging sectors and also intended to cover some of the

developments in nanotechnology and their applicability to food and nutraceuticals systems, together with identifying the outstanding challenges.

Keywords: Nanotechnology, Nano Science, Food Technology, Encapsulation, Nutraceuticals, Processing, Packaging, Additives, Emulsion.

1. Introduction

In today's competitive market new frontier technology is essential to keep leadership in the food and food processing industry. Nanotechnology has emerged as one of the most innovative scientific fields in decades. Nanotechnology involves use of materials on an extremely small scale, usually 0.1 to 200 nanometers. Nanotechnology and nanomaterial's are a natural part of food processing and conventional foods, because the characteristic properties of many foods on nanometer sized components, for example, Nano emulsions and foams. The properties of the recent nanomaterial's offer many new opportunities for food industries, which include more potent food colouring, flavoring, nutritional additives and antimicrobial ingredients for food packaging. Nanotechnology can assist a wide field of food processing area (Chau, 2006). Nanotechnology is increasingly being employed in the areas of food production and packaging (Sanguansri & Augustin, 2006). As with most new and evolving technologies, much emphasis is on the potential benefits of nanotechnology for agriculture, the food industry and likely the consumer. However, not too much is known on safety aspects of the application of nanotechnologies in food production and the incorporation of nanoparticles (NPs) in food products (Maynard 2006). At one billionth of a meter, a nanometer is miniscule - much too small for the human eye to see. And for most humans, anything measuring 100 nm or less may be impossible to comprehend as significant. For this reason, it would seem illogical that structures measuring 1–100 nm would not only exist but would also have implications and applications that could be essential to humankind (Ravichandran, 2009). In food industries, the applications of nanotechnology include Nano particulate Delivery Systems (Nano dispersions and Nano capsules), Packaging (Nano laminates, Nano composites bottles, bins with silver nanoparticles), Food Safety and Biosecurity (Nano sensors) etc. (Chen *et al.* 2006). The Nano scale food additives may be used to influence texture, flavor, nutritious improvement, provide functionally and even detect pathogens and food packaging involves extend food shelf life, edible, Nano wrapper which will envelope foods, preventing gas and moisture exchange, 'smart' packaging (containing Nano-sensors and anti-microbial activators) for detecting food spoilage and releasing Nano-anti-microbes to extend food shelf life (Richardson and Piehowski, 2008; Miller, 2008).

2. Nanotechnology – Science and Technology

Nanotechnology has the potential to impact many aspects of food and agricultural systems. Food security, disease treatment delivery methods, new tools for molecular and cellular biology, new materials for pathogen detection, and protection of the environment are examples of the important links of nanotechnology to the science and engineering of agriculture and food systems. Examples of nanotechnology as a tool for achieving further advancements in the food industry are as follows:

- Increased security of manufacturing, processing, and shipping of food products through sensors for pathogen and contaminant detection.
- Systems that provide integration of sensing, localization, reporting, and remote control of food products (smart/intelligent systems) and security of food processing and transportation.
- Encapsulation and delivery systems that carry, protect, and deliver functional food ingredients to their specific site of action.

Nanomaterials and nanostructures will provide specific function in targeted applications and some examples are listed below,

Type of nanoparticles	Application	Function
Metal nanoparticles (Silver, ZnO)	Food additive/supplement	Enhanced gastrointestinal uptake of metal
	Packaging materials/storage	Increase barrier properties
	Food preparation devices	Clean surface
	Refrigerators, storage containers	Anti-bacterial coating
	Water purification/soil cleaning	Removal/catalysation/ oxidation of contaminants
Sprays	Refrigerators, storage containers	Anti-bacterial coating
Complex nanostructures	Nanosensors in packaging	Detection of food deterioration
Hand-held devices	Storage conditions evaluation	Monitoring of contaminants
Incorporated active nanoparticles	Migration out of packaging materials	Oxygen scavenging, prevention of growth of pathogens
Filters with nano-pores contaminants	Water purification	Removal pathogens
Nano-sized nutrients/foods	Food additives/supplements	Claimed enhanced uptake
Delivery systems (nano-encapsulates)	Food additives/supplements	Protecting and (targeted) delivery of content

The applications of nanotechnology in food and agriculture are new as compared to its use in medicine and pharmaceuticals. The two approaches of nanotechnology; bottom-up and top down build up the basics of this century's frontier technology.

Nevertheless, scientists and industry stakeholders have already identified potential uses of nanotechnology in virtually every segment of the food industry (Fig. 1), from agriculture (e.g., pesticide, fertilizer or vaccine delivery; animal and plant pathogen detection; and targeted genetic engineering) to food processing (e.g., encapsulation of flavor or odor enhancers; food textural or quality improvement; new gelation or viscosifying agents) to food packaging (e.g., pathogen, gas or abuse sensors; anticounterfeiting devices, UV-protection, and stronger, more impermeable polymer films) to nutrient supplements (e.g., nutraceuticals with higher stability and bioavailability).

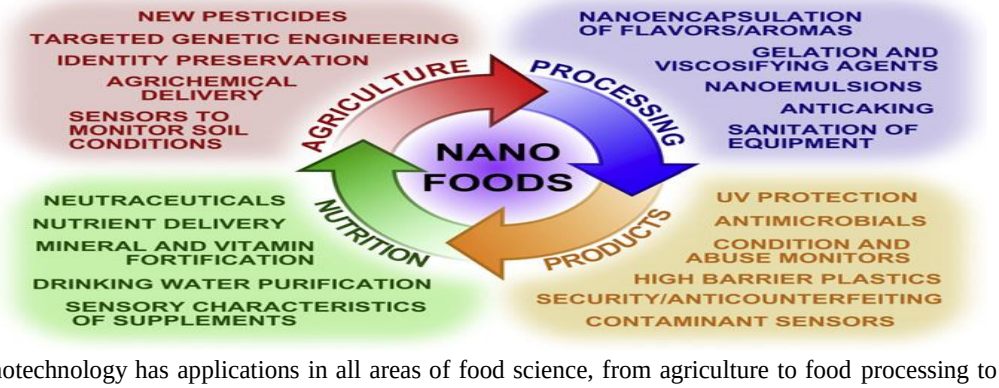

Figure 1 Nanotechnology has applications in all areas of food science, from agriculture to food processing to security to packaging to nutrition and nutraceuticals.

3. **Effect of nanotechnology in food industries**

The achievement of nanotechnology has been recognized by many industries. Even though foods are complex biological systems and also undergo a variety of processing. The rapid development in food industries improved tastes, colour, flavour, texture and consistency of foodstuffs, increased absorption and bioavailability of nutrients and health supplements, new food packaging materials with improved mechanical, barrier and antimicrobial properties, Nano-sensors for traceability and monitoring the condition of food during transport and storage.

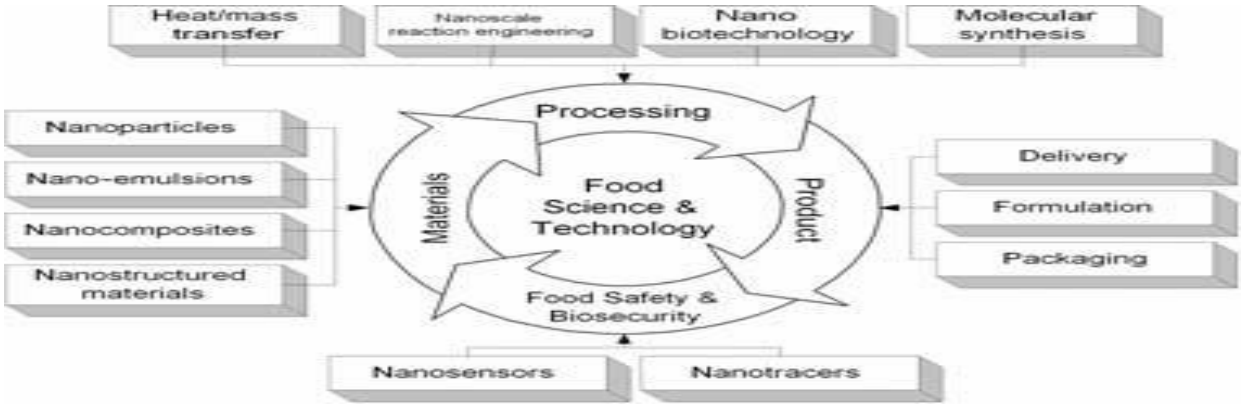

Figure 2 Shows the effect of nanotechnology in food industries

4. Nanotechnology in Food Processing

Cell membranes, harmones, DNA etc., that exist in nature are example of Nano structures and the food molecules, proteins, fats, carbohydrates etc. are not exceptional and the results of nanoscale level murges between sugars, fatty acids and amino acids (Powell and Colin, 2008). 'Nano foods' from the Helmut Kaiser Consultancy (2009) estimates an increasing growth in the development of food and dairy related Nano products and patent applications. The application of nanotechnology with respect to food and dairy industry will be covered under two major heads viz. food additives (Nano inside) and food and dairy packaging (Nano outside).

Strategies to apply Nano science to the food industry are quite different from these more traditional applications of nanotechnology. Food processing is a multi-technological manufacturing industry involving a wide variety of raw materials, high biosafety requirements, and well-regulated technological processes. Four major areas in food production may benefit from nanotechnology:

– Development of new functional materials
– Micro scale and nanoscale processing
– Product development
– Methods and instrumentation design for improved food safety and biosecurity.

4.1. Nano dispersions and Nano capsules

Functional ingredients (for example, drugs, vitamins, antimicrobials, antioxidants, flavorings, colorants, and preservatives etc.,) and comes in different molecular and physical forms such as polarities (polar, nonpolar, amphiphilic), molecular weights (low to high), and physical states (solid, liquid, gas). These ingredients are rarely utilized directly in their pure form; instead, they are often incorporated into some form of delivery system. Uricanu *et al.* (2004) reported that casein micelles (CM) are in effect nano-capsules created by nature to deliver nutrients such as calcium phosphate and protein to the neonate. A novel approach is to harness CM for Nano-encapsulation and stabilization of hydrophobic nutraceutical substances for enrichment of non-fat or low-fat food products. Such Nano-capsules may be incorporated in dairy products without modifying their sensory properties.

4.2. Nano fibers

Nanofibres with diameters from 10 to 1000 nm, makes them ideal for serving as a platform for bacterial cultures as well as structural matrix for artificial foods. Since Nano fibers are usually not composed of food grade substances, they have only a few potential applications in the food industry (Weiss *et al.*, 2006). The food industry can use electrospun microfibers in several ways as under:

- As building elements of the food matrix for imitation/artificial foods, and
- As nanostructured and micro structured scaffolding for bacterial cultures.

4.3. Nanoceuticals

The concept of "nanoceuticals" is gaining popularity and commercial dairy/food and food supplements containing nanoparticles are available (Chen *et al.* 2006; Mozafari *et al.* 2006). The examples of food-related nanoproducts are:

- Carotenoids nanoparticles can be dispersed in water, and can be added to fruit drinks for improved bioavailability;
- Canola oil based Nano sized micellar system is claimed to provide delivery of materials such as vitamins, minerals, or phytochemicals.

4.4. Nano-emulsions

Emulsions are often referred to as "nanoemulsions.", when the use of high-pressure valve homogenizers or microfluidizers often causes emulsions with droplet diameters of less than 100 to 500 nm and functional food components can be incorporated within the droplets, the interfacial region, or the continuous phase (McClements, 2004). This interfacial engineering technology would utilize food-grade ingredients (such as proteins, polysaccharides, and phospholipids) and processing operations (such as homogenization and mixing) that are already widely used in the manufacture of food emulsions (Weiss *et al.* 2006). Nano size emulsion-based ice cream with a lower fat content has been developed by Nestle and Unilever (Renton, 2006).

4.5. Nano-Coatings

Waxy coating is used widely for some foods such as apples and cheeses. Recently, nanotechnology has enabled the development of nanoscale edible coatings as thin as 5 nm wide, which are invisible to the human eye. Edible coatings and films are currently used on a wide variety of foods, including fruits, vegetables, meats, chocolate, cheese, candies, bakery products, and French fries (Morillon *et al.* 2002; Cagri *et al.* 2004; Rhim 2004). These coatings or films could serve as moisture, lipid, and gas barriers.

4.6. Nano encapsulation

Nano encapsulation is defined as a technology to pack substances in miniature making use of techniques such as nanocomposite, nanoemulsification, and nanoestructuration and provides final product functionality that includes controlled release of the core. The protection of bioactive compounds, such as vitamins, antioxidants, proteins, and lipids as well as carbohydrates may be achieved using this technique for the production of functional foods with enhanced functionality and stability. The recent innovation in encapsulation and controlled release technologies, as well as a design principle of novel food delivery systems has been reported. Nano encapsulation can make significant savings for formulators, as it can reduce the amount of active ingredients needed (Huang *et al.*, 2009). Probiotics are generally defined as live mixtures of bacterial species and can be incorporated in foods in the form of yoghurts and yoghurt-type fermented milk, cheese, puddings and fruit based drinks. Encapsulated forms of ingredients achieve longer shelf life of the product.

4.7. Nanomaterial's

Quantum dots (QDs) - immunolabelling has been proved to use for detection of several pathogenic bacteria which is beneficial in food safety aspects. Carbon nanotubes (CNTs) are ideal carriers for delivery of biomolecules by means of their low toxicity and easy penetration to cell membranes in which induce cell death by increasing membrane permeability (Khodakovskaya, 2009). The polymer nanoclay nanocomposite technology has been proven to improve the mechanical, barrier and thermal properties of several synthetic polymers and biopolymers for packaging applications. The incorporation of nanoclay into zein film has also been studied and shown that proper processes together with right chemical affinity between zein and nanoclay would result in physical properties improvement (Luecha *et al.*, 2010).

5. Regulation of nanotechnologies to ensure food safety

The health implications of food processing techniques that produce nanoparticles and nanoscale emulsions also warrant the attention of food regulations. The potential for such foods to pose new health risks must be investigated in order to determine whether or not related new food safety standards are required (Bowman and Hodge, 2007). The European Union regulations for food and food packaging have recommended that for the introduction of new nanotechnology, specific safety standards and testing procedures are required (Halliday, 2007).

6. Conclusion

The prediction is that nanotechnology will transform the entire food industry near future. Nanotechnology has already entered into food and dairy industries, research facilities are established, potential applications are under study. Food nanotechnology advances offers important challenges for both government and industry. The food processing industry must ensure consumer confidence and acceptance of nanofoods. New approaches and standardized test procedures to study the impact of nanoparticles on living cells are urgently needed for the evaluation of potential hazards relating to human exposure to nanoparticles. It is widely expected that nanotechnology- derived food products will be available increasingly to consumers worldwide in the coming years. However, in these recent technological developments leading the way for manufactured nanoparticles to be added to food were discussed. As developments in nanotechnology continue to emerge, its applicability to the food industry will increase potentially.

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