WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.7 (3&4) : 14-17. 2009 *www.world-food.net*

The recent advances in the nanotechnology and its applications in food processing: A review

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Received 14 June 2009, accepted 27 September 2009.

Abstract

The objectives of this paper was to discuss the latest development of nanotechnology, especially in food industries, to give clearer picture about the effect of nanotechnology in food industries and to highlight the latest applications of nanotechnology in food processing industry. However, the risk issues involving the use of nanotechnology in food were also explored. The outcome of this research revealed that the nanotechnology could be useful for controlling and manipulating the matter at the nanoscale level during processing. On the other hand, nanotechnology could also help the consumers to modify the food depending on their own nutritional needs and tastes. However, from health viewpoint, the potential risks of nanoscale materials and the possibility of the accumulation and translocation of nanoparticles in the body should be avoided.

Key words: Nanotechnology, food processing.

Introduction

The potential of nanotechnology have been recognized by many industries, and also commercial products are being manufactured. The main areas of nanotechnology application are in electronics, photonics, pharmaceuticals and cosmetics, food and finishes for surfaces and textiles.

Nanoscience is defined as the study of phenomena and the manipulation of materials at the atomic, molecular and macromolecular scales, where the properties differ from those at a larger scale [1]. It is also explained as the control of matter on an atomic and molecular scale with at least one characteristic dimension measured in nanometer [1]. Moreover, it is defined as the design, production and application of structures, devices and systems through control of the size and shape of the material at nanometre scale [1].

Recently, a lot of things have been discovered such as nanoparticulate delivery systems that play many different roles which are as transportation for carrying the functional materials to the desired site of action, nanoencapsulated food ingredients and additives. Application also provides protective barriers [2] flavour and taste masking, controlled release and better dispersability for water-insoluble food ingredients and additives. Other examples include micronization of ganoderma spore to ultrafine powder by top-down approach, development of nano-scale formulations of different traditional herbal plants and frying oil refining catalytic device. Nanotechnology can assist a wide field of food processing area [3]. The principle of nanotechnology in food processing is focusing more on food preservation and interactive foods. Nanoparticles can be incorporated into existing food to deliver nutrients, increased the absorption of nutrients by the body and also could increase product shelf life. The advantages of nanotechnology in food processing is to develop the texture of food components, encapsulate food components or additives, developing new tastes and sensations, controlling the release of flavours and increasing the bioavailability of nutritional components. On the other hand, the success of these advancements will be dependent on consumer acceptance and the exploration of regulatory issues. Food producers and manufacturers could make great strides in food safety by using nanotechnology, and consumers would reap benefits as well. More than 200 companies are conducting research in nanotechnology and its application to food products [4] and as more of its functionalities become evident, the level of interest is certain to increase.

Unfortunately, nanotechnology application in food industry is still limited. However, the achievement of nanotechnology is beginning to give impact to the food industry, especially from food safety effect to the molecular synthesis of new products and ingredients. Nanotechnology offers many possibilities in food safety and packaging, as an example, gas barrier structures with nanoparticles in plastics that could prevent the diffusion of gas such as oxygen and water vapour by creating tortuous paths. Several recent researchers have reported the nanotechnology as well as its applications in food processing [5, 6, 13, 20, 22]. This article is of potential importance and gives good information to the food processors in order to design operation units of food processing. Accordingly, this review paper has been justified.

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 discoveries made in nanotechnology also give impact to the food industry, due to the effect of biological and biochemical functionality of the system during the processing. Therefore, nanotechnology tries to help this problem to measure, control and manipulate the matter at the nanoscale level to change those properties and functions in a beneficial way [3]. Besides that nanotechnology is also used as a means to understand how physicochemical characteristics of nano-sized substance can change the structure, texture and quality of foodstuffs [2]. Many major areas in food production may benefit from nanotechnology which is development of new functional materials, microscale and nanoscale processing, product development and methods, instrumentation design for improved food safety and biosecurity, storage, transportation and traceability [2, 3] .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[7]. Fig. 1 shows the effect of nanotechnology in food industries.

The latest emerging application in food nanotechnology: Revolutionary for science and technology is likely to design and control fabrication and integration of nanomaterial and nanodevice[7]. The development of nanotechnology and production of nanoproducts makes it almost certain that nanotechnology will have both direct and indirect impacts on food industry. There are a large number of potential applications of nanotechnology [3] within the food industry (Table 1). An example of the application of nanotechnology to the production of food is the creation of functional foods [6]. These are products that promise consumer improvements in targeted physiological functions [9]. Sometimes the integration of two or more technologies will open up to the new opportunities for the development of nanotechnology. As an example, the integration of biotechnology, nanotechnology and IT has produced the nano-biosensors for the detection of pathogens, contaminants in food and also the condition of food during transport or storage. Besides that, such integration of technologies also leads to the development of an "electronic tongue" by combination of taste receptors and flavour perception [2]. The

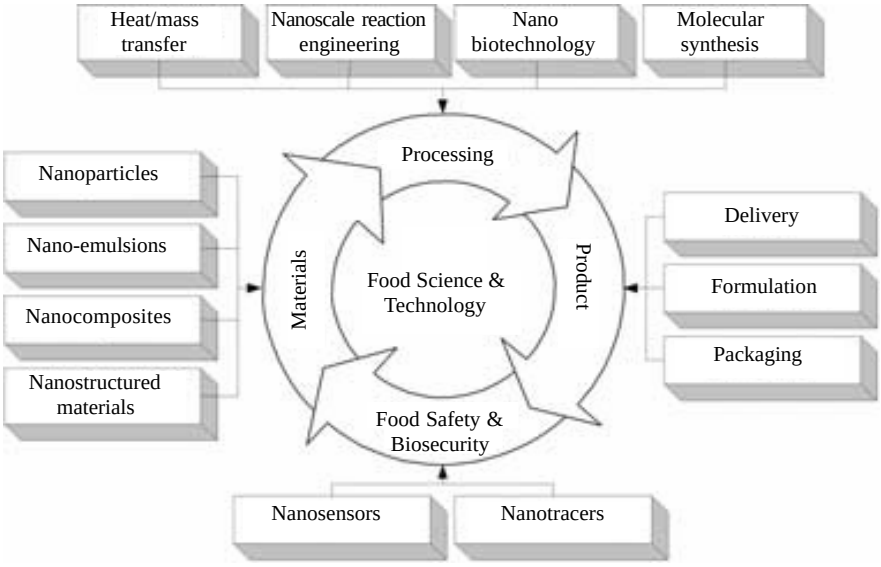

Figure 1. Controlled release of nanotechnology in food [8].

Table 1. Examples of nanotechnology researches, nanoproducts and applications of nanotechnology in food processing [3].

Category	Examples of the different applications	Reference
Food processing	•Interactive foods and beverages give desired flavours and colors (on-demand delivery) by the addition of nanocapsules which burst at different microwave frequencies	ETC Group [4]
	•The Israel National Nanotechnology Initiative in collaboration with the U.S. National Nanotechnology Initiative has explored the applications of nanotechnology in water purification and treatment focusing on the areas such as membranes and membrane processes, biofouling and disinfection, and contaminants removal	INNI [8]
	•Development of nano-scale formulations of different traditional herbal plants by reducing the herbs to nanoscale powder or emulsion	ElAmin [11]
	•Micronization of ganoderma spore to ultrafine powder by top-down approach, resulting in the rupture of cell walls and release of potential active ingredients	Liu *et al.* [12]
	•Frying oil refining catalytic device (made of nanoceramic material) inhibits thermal polymerization of frying oil and reduce off-odors	OilFresh [13]
	•Micrometres long stiff hollow nanotubes made of milk protein by self-assembly have potential to be used as novel ingredients for viscosifying, gelation, nanoencapsulation, and controlled release purposes	Graveland-Bikkera and de Kruifa [9]

applications of nano-based technology in food industry may include nanoparticulate delivery systems (micelles, liposomes, nano-emulsions, biopolymeric nanoparticles and cubosomes) for food safety and biosecurity (nano-sensors and nano-toxicity) [4, 8, 9]. Worldwide sales of nanotechnology products to the food and beverage packaging sector jumped from US$ 150 million in 2002 to US$ 860 million in 2004. The value of the application of nanotechnology in food is expected to surge to US$ 20.4 billion in 2010 [10]. Although many food scientists would claim that the industry has already embraced nanotechnology, only limited researches in nanotechnology have been performed in foods and food-related products, and the global development of nano-foods is indeed on its initial stage.

The developments of nanotechnology in food processing is focused more on the texture of food components, encapsulating food components or additives, developing new tastes and sensations, controlling the release of flavours and increasing the bioavailability of nutritional components [2].

There are a lot of functional materials such as vitamins, antimicrobials, antioxidants, flavourings, colorants and preservatives used in food industries. These functional materials come in wide of different molecular and physical forms (polarities, molecular weights and physical states) [3]. These functional materials should be protected from any deterioration during food processing, storage and utilization. An important factor that affects the efficacy of food materials in food industries is a delivery system for nutrients and supplements [2]. Delivery system plays many different roles in transportation for carrying the functional materials to the desired site of action. In delivery system, the functional materials also have been protected from chemical or biological degradation to maintain the functional materials in active state. Beside that, delivery system may be capable of controlling the release of the functional material, such as the release rate or the specific environmental conditions that trigger release. Furthermore, delivery system has to be compatible with the other components in the system, as well as being compatible with the physicochemical and qualitative attributes such as appearance, texture, taste and shelf life of the final product [3]. Due to the importance of functional materials in delivery system, therefore delivery system has been developed to encapsulate functional materials including simple solutions, colloids, emulsions, biopolymer matrices and others [3]. Recently, self-assembled nanotubes have been developed from hydrolysed milk protein α-lactalbumin, which can offer a new naturally derived carrier for nanoencapsulation of nutrients, supplements and pharmaceuticals [9]. Nanoencapsulation of food ingredients and additives is one of the major areas of nanotechnology application. Nanoencapsulated products are interactive foods, which will allow consumers to modify the food depending on their own nutritional needs and tastes. Nanoencapsulated food ingredients and additives also provide protective barriers, flavour and taste masking, controlled release and better dispersability for water-insoluble food ingredients and additives [2]. Nanocapsules can be incorporated into food to deliver nutrients. Addition of nanoparticles to existing food can enable increased absorption of nutrients. Another key application is additives which could easily be absorbed by the body and could increase product shelf life. Nano-size dispersions, emulsions and filled micelles have the advantage that they are not subjected to sedimentation which gives better product life span and storage. As their size is much smaller than the wavelength of light, they can be incorporated in clear and transparent foods without causing muddiness. Substances difficult to dissolve can more easily be absorbed by the body if they are of nano-scale size due to their large surface area. If the active substance is to be protected during storage or passage through the intestines the existing nanotechnology can produce perfect protective layers. It is also possible to taylor protective layers to release active substances in an "intelligent" way, e.g. by a change of pH-value.

Risks of nanotechnology in food sector: In the future, the food industry plans to realize the potentials of nanotechnology to extend shelf life customize flavours, improve human health and well being. Instead of advantages aspects, nanotechnology also gives disadvantages, especially the effect to the human health and environment, and many sectors will receive the risk of nanotechnology application, the major worried focusing more on the effect of nanotechnology on human health. Nanotechnology foods with tangible benefits for the consumer will be easier to market than nanotechnology foods without obvious consumer benefits. For the industry, it might be tempting to assume that attitudes toward nanotechnology foods will be more positive if a nanotechnology product with a desirable benefit is on the market. Generally, the impacts of nanoparticles on the body depends on the properties such as particle size, mass, chemical composition, surface properties and how the individual nanoparticles are aggregating together. The sites of penetration, possible accumulation and translocation of nanoparticles in the body may also determine the potential risks of nanoscale materials [3]. In March 2006, it was reported that more than 70 people suffered from respiratory problems and were hospitalized after using the nanotechnology bathroom cleaner [4]. There are a lot of food substances and ingredients which have nanostructure in nature. However, the entry of manufactured nanoparticles into food chain may result in accumulation of toxic contaminants in foods, adversely affecting human health. However, there are also nanoparticle products with no harmful effects. As an example, the toxicity of certain substances such as selenium might be significantly reduced while its particle size was decreased to nanoscale [3]. Besides that, most people prefer the natural food although the healthfulness of natural and artificial foods were specified to be equivalent. Therefore, the number of food products containing nano-scale substances is still low in the market [14].

Public perception of nanotechnology: To ensure rapid development of nanotechnology and promote economic growth, many nanotechnology initiatives such as commissions or centres have been launched. Besides that, there are also proposed regulation to improve the protection of human health and the environment [15]. While most of the information provided by the government agencies in mainland China and Taiwan is presented in Chinese, this article would provide useful information such as the certification system "Nano Mark" of nano-products for different parts of the world in developing the certification system for nanotechnology food products [13]. From an international marketing perspective, a restrictive regulation may discourage the innovation and marketing of nanotechnology, leading to an impediment to the growth and development of nano-food industry [14]. As an oversight of nanotechnology is to nurture

beneficial technologies rather than stifle them, it is important to keep a balance between "too strict" and "too loose" in developing the standard, definition and regulation for nano-foods. Furthermore, an updated scientific evidence of nano-toxicity in close link with the newly innovative nano-products would be essential for the development of updated regulations for nano-foods to minimize the possible impacts of nanotechnology on health. However, public perception may differ from the experts' assessments [15]. Public perception of nanotechnology is very limited. A number of studies have examined on public perception of nanotechnology in the US and in Europe. Results of these studies show that public knowledge about nanotechnology is very limited [16]. Even though the US public possesses little knowledge about nanotechnology, a majority is convinced that benefits outweigh the risks [16]. In Europe, the public seems to be less optimistic about nanotechnology [17]. However, most studies focusing on public attitudes toward nanotechnology have examined attitudes toward nanotechnology in the abstract [17]. Introducing such novel foods is unlikely to result, generally, in more positive attitudes toward nanotechnology food [18]. It is more likely that, for some products, nanotechnology food is accepted, but not for other products.

Conclusions

Nanotechnology, nanoscience and nanobiotechnology are concerned with the understanding and rational manipulation of materials at the atomic and molecular levels. In its widest sense, nanotechnology is a natural part of food processing and conventional foods because the characteristic properties of many foods rely on nanometre-sized components. However, in this review paper 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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