IMPACT OF NANOTECHNOLOGY IN FOOD INDUSTRY

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***Abstract*- Nanotechnology has a multiple role in food industry, and as forecasted, its importance is increasing. Nanomaterials are used in food production or inspection, either in form of new materials with unique, nano-sized dispersity, providing new physico-chemical characteristics for these substances, or as novel methodologies utilizing nanostructures in analytical or technological processes. As food microbiology is affected, nanotechnology provides novel agents to inhibit growth of spoilage and pathogenic microbes, to prevent their attachment to surfaces, and even to eliminate them.**

Nanotechnology is very interesting for scientists as an invisible world science. This paper answers basic questions about using of nanotechnology in food sector and summarizes applications of nanotechnology in food microbiology field and Other applications provide tools for investigating microbes by detecting their attachment to food contact surfaces or specifying microbes and their growth. The new form of disparity affects not only the activity of a given element or molecule against microorganisms, but also modifies metabolic and material transport systems of uni- and multicellular organisms. Food safety applications such as antimicrobial activity of nano-particles, nano-sensors for microbial detection and food packaging nano-materials were discussed. But nanotechnology applications need some precautions to avoid its toxicological and negative effects for human and environment.

I. INTRODUCTION

A nanomaterial is defined as an “insoluble or biopersistent and intentionally manufactured material with one or more external dimensions, or an internal structure, on the scale from 1 to 100 nanometres” as detailed in the recent EC Cosmetics Regulation. Efforts are underway to establish a more comprehensive definition for nanomaterials. Hence, this is a provisional term until a uniform, European and international definition is made available. Nanotechnology refers to a broad area of technological activity focused on the engineering and manipulation of these nanomaterials or nanoscale structures. As the physico-chemical properties of nanostructures are not governed by the same laws as larger structures, but by quantum mechanics, it is observed that these materials do not behave like their macroscale counterparts, and unique properties arise at the nanoscale. Most probably due to the higher surface/volume ratio (dispersity), colour, solubility, diffusivity, material strength, toxicity, also thermodynamic, magnetic, optical and other properties will be very different at the nanoscale as compared to the macroscale. At present nanotechnology is being used in a range of applications, from the design of computer chip layouts and new polymers to commercial applications as in cosmetics and suntan lotions, drug delivery, surface coatings, and there is also the potential for food industry.

The science of applied nano-technology is concerned with the characterisation, production and targeted modification of naturally-occurring or synthetically manufactured materials at the atomic, molecular or colloidal level. While the original definition of nanotechnology referred to all structures having a characteristic size of less than 100 nanometres (10–7 m) in at least one dimension (see glossary), in recent years the definition of nano-structured materials has been limited to materials which show entirely new physical and chemical properties and which therefore differ considerably from macro-scaled materials with the same chemical structure. These divergent properties of nanoscaled materials are frequently the result of extreme surface-to-volume ratios of the particles and are the reason why boundary layer phenomena are decisive for the physical and chemical properties of these materials. Thus, for example, many nano-scaled materials have a substantially higher chemical reactivity and entirely different interaction behavior with electromagnetic waves than macroscopically structured materials. These different properties necessitate special toxicological considerations . At the same time, however, these represent the basis for special industrial applications and possible advantages for the consumer. Besides machine production, electrical engineering, textile finishing and pharmaceutics, this also applies to the food industry . The present contribution will focus primarily upon applications in the food industry.

II. INDIRECT APPLICATIONS OF NANOTECHNOLOGY IN FOODSTUFFS

Four principal potential applications of nanotechnology in which intensive research is currently in progress can be identified in the food industry: packaging, process technology, microbiology and ingredients . Its use in foodstuffs can be classified as “direct” or “indirect”.

Direct use refers to the integration of nano-structured substances and materials in foodstuffs and mustalso be declared as such.

Indirect use includes e.g. the use of nano-structured materials in packaging technology or the use of efficiently nano-structured catalysers for the hydration of fats . It can therefore be expected that the majority of applications of nano -technology are concerned with its indirect use.

a. Use in packaging technology

For a number of years nanotechnological approaches have been used to improve the functional properties of packaging materials [4, 12–14]. The principal focus is upon the development of new packaging materials which prolong the shelf lives of foodstuffs as a result of improved protective functions (Figure 1). Thus, for example, the inclusion of impermeable nano-scaled bleaching earth mono-layers incorporated in a compound following chemical modification can reduce gas exchange (oxygen, nitrogen, carbon dioxide, etc.) with the environment [8]. Besides improving the barrier function of the packaging material, the incorporation of nano-scaled structures also substantially improves the mechanical properties of the packaging, such as the abrasion resistance Nano-scaled carrier systems for anti-oxidants and preservatives incorporated in packaging materials can transform "passive" packaging to "active" packaging and thus prolong the shelf life of the foodstuffs [15, 16]. The incorporation of nanosensors and tracers which, with their increased sensitivity, can recognize and indicate even the smallest changes in the packaged goods (e.g.rotting or interruption of the refrigeration chain), make possible intelligent packaging able to indicate the presence of oxidation products or microbiologically produced secondary metabolites which can impair the quality or safety of the foodstuffs [6, 15, 16].

In addition, nanotechnology allows the modification of other functionalities, such as the processability of packaging machines, optical properties (transparency), biological degradability, wetting behaviour and the application of heat in microwave ovens.

b. Use in food processing technology

At the present time nanotechnology finds only limited use in food processing technology, although this situation could rapidly change. New research results which show dramatically different catalysation behavior for nano-structured metal particles offer particular promise [9].
Accordingly, it would then be possible not only to accelerate reactions by a corresponding design, but also to control the reaction paths and consequently the concentrations and types of the products generated. Specific applications include the reduced formation of trans-fatty acids during the hydration of fats and the accelerated production of proteincarbohydrate conjugates for the stabilization of foodstuff emulsions

c. Use in food microbiology

In the area of food microbiology (cf. _ Box 1) there are two different fields of application (_ Figure 1): (1) developing nano-sensors and (2) improving the effectiveness of preservatives, i.e. materials which inhibit the growth of or kill microorganisms [15, 19, 21–23]. However, as in this case nano-structures must be added directly to the foodstuffs the latter application must be allocated to the direct use of nanotechnology in foodstuffs.

d. Direct use of nanotechnology in foodstuffs

The direct application of nano-structured materials in foodstuffs [5, 7, 11, 24–29] is of particular interest. Possibilities exist here for the incorporation of functional foodstuff ingredients, such as fragrances, colouring agents, anti-oxidants, preservatives (see above) and biologically active components (vitamins, omega-3 fatty acids, polyphenols, etc.) in nano-structured particles or fibrous structures. In this respect, the possible advantages of improved bioavailability must be weighed against the risks of a possible overdosis (see below). This requires further research. Thus, the modification of the pharmacokinetics of biologically active materials for use in these carrier systems could require rethinking of the permissible concentrations, as the risk of over-dosage during consumption then increases [7]. On the other hand, it is possible that the use of nano-scaled substances reduces unwanted substances, such as salt, fat or sugar, in foodstuffs.

The requirement for the use of new material structures as functional foodstuff ingredients is justified by their frequently inadequate physical and chemical stability in foodstuff matrices [26, 27]. Due to their chemical structure these ingredients can be optimally incorporated in the existing biological structures (cells and cell compartments such as vacuoles or membranes) of the starting material, e.g. fresh fruit or vegetables and thus stabilise these. On the other hand, in processed foods these materials are subject to rapid oxidation or polymerisation reactions following their incorporation, detrimentally affecting the quality of the respective foodstuff. The incorporation of components in nano-structured carrier systems can greatly reduce the extent of such destabilizing reactions and prevent the physical separation of the components from the foodstuff matrix [29].

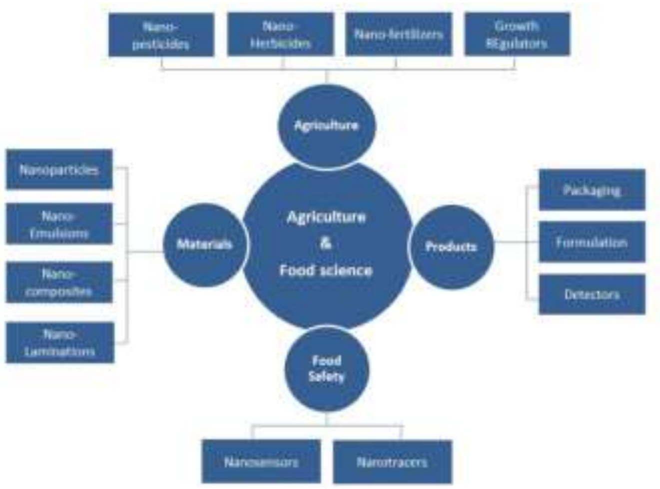

Figure 1: Schematic overview of the potential area of application of nanotechnology in food industry

III. NANOTECHNOLOGY IN FOOD MICROBIOLOGY

Nanotechnology has potential applications in all aspects of food chain including storage, quality monitoring, food processing, and food packaging. Nanotechnology applications in the food industry range from intelligent packaging to creation of on demand interactive food that allows consumers to modify food, depending on the nutritional needs and tastes (Neethirajan and Jayas, 2011). Food microbiologists are interested in safety and quality assurance programs to produce safe and high-quality food products which have zero defects and free of pathogens. The main applications of nanotechnology in food safety programs are antimicrobial effect of nanoparticles and nanosensors for detection of pathogens and contaminating microorganisms.

a. Antimicrobial effect of nanoparticles

The inhibition of microbial growth due to surface contact with the silver-silica nanocomposite- ontaining polystyrene demonstrated that materials functionalized with the silver nanocomposite have excellent antimicrobial properties (Egger *et al.*, 2009). Cationic peptides nanoparticles form -helices or -sheet-like structures that can insert into and subsequently disintegrate negatively charged bacterial cell surfaces.

These nanoparticles formed by self assembly of an amphiphilic peptide have strong antimicrobial properties against a range of bacteria, yeasts and fungi. The nanoparticles show a high therapeutic index against *Staphylococcus aureus* infection in mice (Liu *et al.*, 2009). Metal oxide nanoparticles, especially TiO2 and Ag2O nanoparticles, have demonstrated significant antibacterial activity. They can also be effective against eukaryotic infectious agents (Allahverdiyev *et al.*, 2014). Silver nanoparticles can be prepared by simple green synthesis method using *Plectranthus amboinicus* leaf extract which acts as both reducing and capping agents. Morphological studies show the formation of nearly spherical nanoparticles. The synthesized Ag nanoparticles exhibited better antimicrobial property towards *Escherichia coli* and *Penicillium* spp. Than other tested microorganisms using disc diffusion method (Ajitha *et al.*, 2014).

Nanocapsulation can be used to apply antimicrobial activity by nanotechnology. Donsi *et al.* (2010) found that, encapsulation of essential oils into nanometric delivery systems for incorporation into fruit juices enhance their antimicrobial activity while minimizing the impact on the quality attributes of the final product. Also, Ravichandran *et al.* (2011) reported that, Encapsulation of benzoic acid (1,100 μg/mL) in polylactic-co-glycolic acid nanoparticles inhibited *Listeria monocytogenes, Salmonella typhimurium* and *Escherichia coli* in raw and cooked chicken meat systems.

Nanoparticle delivery of benzoic acid was effective against *S. typhimurium* and *L. monocytogenes* (1.0 and 1.6 log CFU/g reduction of *S. typhimurium* and 1.1 and 3.2 log CFU/g reduction of *L. monocytogenes* compared with 1.2 log CFU/g without nanoparticles on the days 9 and 14 of storage, respectively). These findings demonstrate the efficacy of phenolics as natural and safer compounds on pathogen reduction delivered by nanoparticles and their potential for commercial food safety applications.

Nanocapsulation improves the rate of inhibition compared with conventional delivery and retains the antimicrobial efficacy for a longer time. Moreover, Chopra *et al.* (2014) evaluated the antibacterial activity of Nisin loaded chitosan/carageenan nanocapsules, results indicated that encapsulated nanocapsules showed better antibacterial effect on microbe's (*Micrococcus luteus*, *Pseudomonas aeruginosa*, *Salmonellaenteric*, and *Enterobactor aerogenes*)*in vitro* as well as in tomato juice for prolonged periods (6 months) as compared to the components evaluated separately.

b. Nanotechnology in food packaging

Nano food packaging materials may extend food life, improve food safety, alert consumers that food is contaminated or spoiled, repair tears in packaging, and even elease preservatives to extend the life of food in the package by increasing the barrier properties (Sekhon, 2010). Food packaging nano-materials collect applications of nanosensors for microbial detection and antimicrobial activity of nanoparticles. Intelligent food packaging, incorporating nanosensors, could even provide consumers with information on the state of the food inside. Food packages are embedded with nanoparticles that alert consumers when a product is no longer safe to eat. In fact, nanotechnology is going to change the fabrication of the entire packaging industry (Sekhon, 2010). Antimicrobial nanoparticles that have been synthesized and tested for applications in antimicrobial packaging and food storage boxes include silver oxide nanoparticles (Sondi and Salopek-Sondi, 2004), zinc oxide, and magnesium oxide nanoparticles (Jones *et al*. 2008) and nisin particles produced from the fermentation of a bacteria (Gadang *et al*. 2008). Commercial nanocomposite food packaging type nanosilver containers were characterised using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). The presence of nanoparticles consistent with the incorporation of 1% nano-silver (Ag) and 0.1% titanium dioxide (TiO2) nanoparticle into polymeric materials formed into food containers was confirmed, results indicated that both nano-materials used in this type of packaging appear to be embedded in a layered configuration within the bulk polymer (Metak and Ajaal, 2013). Thus, Kanmani and Rhim (2014) reported that commonly used antimicrobial nanocomposite materials for food packaging include metal ions (silver, copper, gold, platinum), metal oxide (titanium dioxide, zinc oxide, magnesium oxide), organically modified nanoclay, natural biopolymers (chitosan), natural antimicrobial agents (nisin, thymol, carvacrol, isothiocyanate, antibiotics).

c. Toxicological and negative effects of nanoparticles

The application of nanotechnology in food has, therefore, led to concerns that ingestion of nano-sized ingredients and additives through food and drinks may pose certain hazards to consumer health. Such concerns have arisen from a growing body of scientific evidence which indicates that free engineered nanoparticles can cross cellular barriers and that exposure to some forms can lead to increased production of oxyradicals and, consequently, oxidative damage to the cell (Li *et al*. 2003; Donaldson *et al*. 2004; Oberdorster, 2004; Geiser *et al*. 2005).

Nanoparticles are for instance incorporated to increase the barrier properties of packaging materials (e.g., silicate nanoparticles, nanocomposites, and nanosilver, magnesium and zinc-oxide). When the nanoparticles are applied into the food packaging materials, direct contact with food is only possible following migration of the nanoparticles. The migration of metals from biodegradable starch/clay nanocomposite films used in packaging materials for its gas barrier properties to vegetable samples was shown to be minimal (Avella *et al*., 2005). Moreover, Impellitteri *et al.* (2009) found that after exposure of Ag nanoparticles to the hypochlorite/detergent solution, a significant portion (more than 50%) of the sock nanoparticles were converted, in situ, to AgCl and suggested that an oxidation step is necessary for the elemental Ag nanoparticles to transform into AgCl. In addition, the efficacy of Ag, as an antimicrobial agent in fabrics, may be limited, or even negated, after washing in solutions containing oxidizers. In another study, silver migration was observed for all samples of three commercial nanosilver plastic food containers, with the total silver migration values ranging between 1.66 and 31.46 ng/cm2 (Echegoyen and Nerín, 2013).

IV. Conclusion

In conclusion, nanotechnology is a promising applicable science in food microbiology field. Although nanoparticles are present in nature but it can be mimicked in applicable forms to add new features to nano-materials. For food applications, nanotechnology can be applied by two different approaches, either bottom up or top down . Structures on nano-scale have been shown to have unique and novel functional properties. Greater surface area of nanoparticles per mass unit is expected to be more biologically active than larger sized particles of the same chemical composition. In contrast nanocomposite has lower effective activity than ions, molecules or solutions of the same compounds, but it has another advantages and benefits in applications for long-term activity.

Nanotechnology has great advantages for food safety applications such as antimicrobial activity of nanoparticles, nanosensors for microbial detection and food packaging nano-materials. But nanotechnology applications need some precautions to avoid its toxicological and negative effects for human and environment.

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