

## NANOTECHNOLOGY PERSPECTIVES IN AGRO AND FOOD INDUSTRIES

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**Abstract:** Nanotechnology is a rapidly emerging field of research with enormous potential for societal and economic benefits. It exploits physical phenomena and mechanisms that cannot be derived by simply scaling down the associated bulk structures and bulk phenomena. In this article nanotechnology perspectives and applications in agro and food industries has been analyzed. Development and perspectives for intelligent packaging materials and encapsulated components for slow release of active compounds has been especially reviewed.

**Key words:** nanotechnology, nanofood, food packaging

### Introduction

In natural and man-made environment, it is expected that nanotechnology can help to solve problems like soil and groundwater remediation, air purification, pollution detection and it is expected to have strong impact on agro and food industries (fig. 1.).

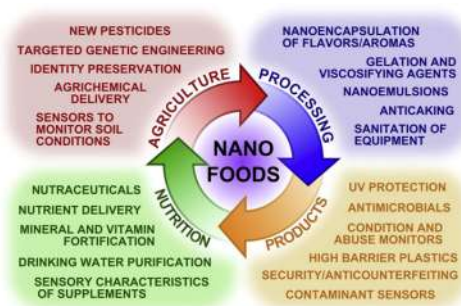


Figure 2. Nanotechnology in agro and food industries

Agriculture may benefit from advances in nanotechnology which will not only develop new nanostructured biocatalysts in order to modify the agroresources in the green chemistry context, but will also decrease and optimize the use of nanoparticles pesticides, increase the efficiency of nanostructure biodegradable materials, develop autonomous nanosensors for real-time monitoring and develop the smart delivery of nanosystems for prevention, improved diagnostics and treatment. The recovery of useful materials like nano-Si directly from plant raw materials can be of strategic importance

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for industrial processes in numerous countries. The process has a number of important advantages over that of mineral origin, since it involves less steps since each plant species has a constant chemical composition, and the final product contains only a narrow range of metal oxide impurities. As a result an improvement of the agricultural techniques for the production of both healthy food and well-suited resources for non-food uses as materials or biofuels will be enabled. Increasing demands for more efficient food production and processing, the possibility of engineering food for improved nutrition and the development of foodstuffs designed to be suitable for people with various nutritional disorders, will all require a step change in our ability to manipulate the structure of materials at the nanoscale. According to EU commission recommendation [1], these type of materials are defined as “natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm”. It should be mentioned, that in specific cases and where warranted by concerns for the environment, health, safety or competitiveness, the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 %. Furthermore, material can be considered as nanomaterial, if the specific surface area by volume of the material is greater than  $60 \text{ m}^2 / \text{cm}^3$ . Also, graphene flakes and single wall carbon nanotubes with one or more external dimensions below 1 nm, as well as quantum dots should be considered as nanomaterial as well.

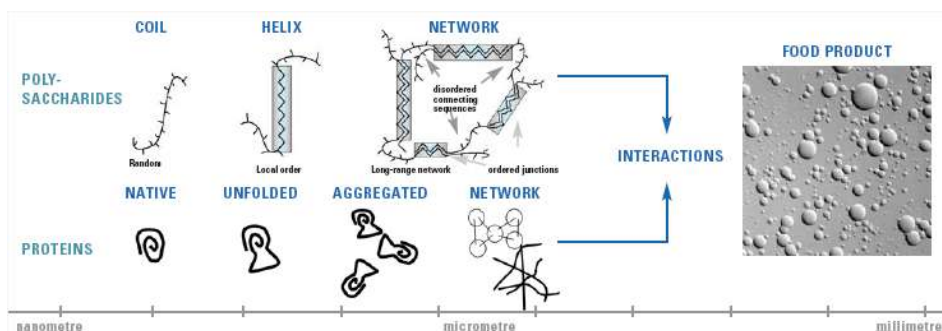


Figure 2. The food length scale structure

Although an upper limit of 100 nm is commonly used by general consensus, it is acknowledged that there are an increasing number of particles which are engineered to have internal nanoscale features, like core-shell particles, nano-encapsulates and various aggregates, agglomerates and multicomponent assemblies. Therefore the International Organization for Standardization (ISO) acknowledged that health and safety considerations associated with intentionally produced and incidental nano-objects do not abruptly end at dimensions of 100 nm and that it is clear that a robust terminology will need to capture and convey effectively the performance aspects of intentionally produced nano-objects and nanostructured materials in their definitions,

apart from their fundamental size and shape [2]. For this reason U.S. Department of Health and Human Services Food and Drug Administration (FDA) consider evaluation of materials or end products engineered to exhibit properties or phenomena attributable to dimensions up to 1,000 nm, as a means to screen materials for further examination and to determine whether these materials exhibit properties or phenomena attributable to their dimension(s) and associated with the application of nanotechnology [3].

For all nanomaterials dimension-dependent and surface phenomena become more important compared to bulk phenomena, while quantum effects change the way how nano systems work. In agro and food industries dimension-dependent properties or phenomena of nanomaterials may be used for various functional effects such as increased bioavailability or decreased toxicity of products, better detection of pathogens, improved food packaging materials, or improved delivery of nutrients. Since these effects may derive from altered or unique characteristics of materials in the nanoscale range that are not normally observed or expected in larger-scale materials with the same chemical composition, such changes raise questions about the safety, effectiveness, performance, quality or public health impact of nanotechnology products. Therefore, considerations such as routes of exposure, dosage, and behavior in various biological systems are critical for evaluating the safety, effectiveness, public health impact, or regulatory status of a wide array of this type of products.

### **Nanotechnologies in agro and food science and industries**

Food as a nanocomposite material is often a complex mixture of proteins, (poly-) saccharides, fats, water, vitamins, anti-oxidants, microorganisms, colorants, and salt. Functional ingredients are essential components in many foods e.g., vitamins, colors, flavors, preservatives, antimicrobials, etc. In the food manufacturing process, the additive surface functional nanoparticles can increase nutrition absorption and food bioavailability and significantly improve food flavor, color and texture. On food market, there are already various nanoproducts like nanoscale ingredients that scavenge more free radicals, increase hydration, balance the body's pH, reduce lactic acid during exercise, the surface tension of foods and increase wetness and absorption of nutrients. Processing of food additives, especially flavor compounds by creating micro and nano particles based on supporting polymer materials has been studied intensively in recent years [4,5]. It has been established that thermal and chemical stability of active compounds under various food processing is the main request for their applications in food technology and that immobilization improves the stability of active compounds and overcomes some of the limitations and negative effects of food processes [6,7]. Numerous investigations showed that the productions of polymer films that contain active compounds by electrospinning process allow the formation of complex microparticles and nano-scale fibers which can be used as carriers for immobilization of various materials like a drugs or food additive [7]. Our research in this field has shown that it is possible to successfully use this technique for immobilization of various flavors including ethyl vanillin and D-limonene. The formation of these composite materials is result of action of several parameters: intensity of applied electrical potential, polymer characteristics (i.e. viscosity, conductivity and surface tension), flow rate of polymer

solution and distance between two charged electrodes (i.e. needle and collector) (Fig.3). Beside electrospinning many other techniques like electrostatic extrusion, air atomization, spray-congealing and dripping techniques are developed for encapsulation of probiotic bacteria in Ca alginate beads as additional protection of microorganism, formation of solid liquid micro particles as food carriers for food additives, natural zeolites encapsulation in Ca-alginate for heavy metals removal etc.

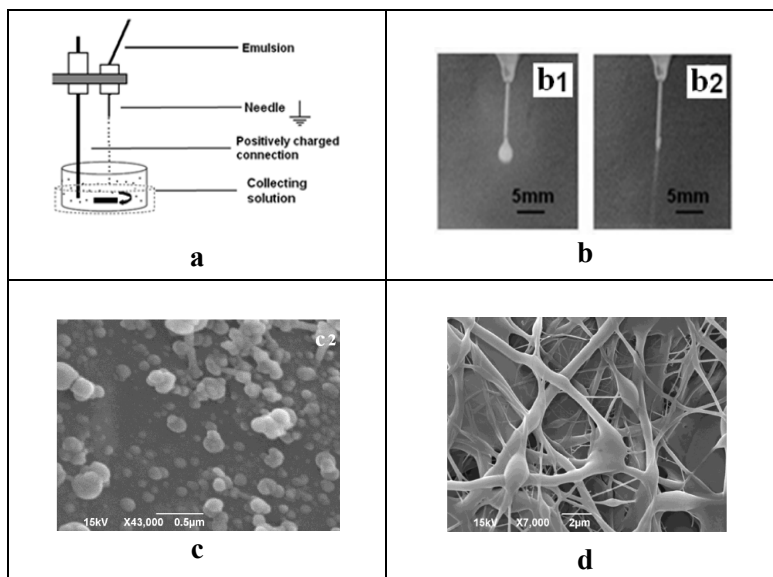


Figure 3. Schematic of the electrostatic immobilization process (a); photographs of effects of 0 kV (b1) and 6.5 kV (b2) applied voltage on emulsion flow and droplets formation; microstructures of immobilized ethyl vanillin flavor, particles (c), fibers (d)

Another concept for controlled release of active compounds such as antimicrobials, antioxidants, enzymes, flavors and nutraceuticals is based on controlled releasing packaging. Controlled releasing packaging (CRP) belongs to a group of food packaging technologies known as active packaging, which provide additional functions that in some way enable package to interact with food to improve its quality, safety and convenience. Antimicrobial and antioxidant packaging are two types of CRP which are especially important and numerous research has been performed in order to develop these types of nanotechnologies. In the field of antimicrobial packaging several categories of antimicrobials have been tested for antimicrobial packaging applications: organic acids, fungicides, bacteriocins, proteins, enzymes silver substitute zeolite and others. In order to further develop this type of packaging the behavior of hazardous food-borne microorganisms in the presence of antimicrobial packaging must be understood. As mentioned above, another major type of CRP is antioxidant packaging, in which antioxidants are incorporated into or coated onto food materials to reduce oxidation in the packed food. In recent years there is a growing interest to use vitamin E (tocopherols) as a

natural antioxidant in food packaging. Besides being an effective antioxidant for reducing oxidation in foods it has been found that tocopherols can stabilize polymer processing which enable this material to serve dual functions when added to packaging.

Beside active packaging numerous research is performed in the field of “intelligent” packaging, which refers to the concept of monitoring information about the quality of the packed food, by incorporating into packaging materials various nanotechnology based nano-sensors or nano-capsules [8]. This type of packaging may incorporate various other concepts such as “Release-on-Command” concept which will provide a basis for intelligent preservative packaging technology that will release a preservative if food begins to spoil, “Electronic Tongue” concept, which can monitor and signal the condition of the packed food and Radio Frequency Identification Display (RFID) which displays involve utilization of smart labels that will assist quick and accurate distribution of a wide variety of goods with limited shelf-life.

Besides active and intelligent packaging there are two other categories of food packaging which involve the use of nanotechnology: nanoparticles (NPs) reinforced packaging and biodegradable nano-composites food packaging. NPs-reinforced packaging use NPs to dramatically improve the mechanical performance, such as flexibility, reduced gaseous permeation, stability of temperature and humidity, and ultraviolet light and flame resistance, of packaging materials, while the biodegradable nano-composite food packaging category involves new types of biodegradable materials, which in general can be made of polylactic acid (PLA) and nanosized montmorillonite (MMT). It has been found that composites made of polylactic acid (PLA) and nano-sized MMT could improve the fire-resistance; polyethylene (PE)-MMT and PE-silica (SiO<sub>2</sub>) composites improved durability; a nano-composite synthesized by polyvinyl chloride (PVC) and MMT could improve the property of optical resistance. A novel composite prepared by polyamide and multiwall carbon nanotube (MWNT) offered significant flame-resistant properties while another composite composed of polymer and nano-sized MMT improved gas barrier properties of food packaging material.

Although, utilization of nanocomposites in food packaging has become one of the most developed areas in the food industry, the migration of NPs from packaging to packed food raised public concern. The main risk of consumer exposure to NPs from food packaging is likely to be through potential migration of NPs into food and drink. In general, two types of mechanism can be adopted to explain the toxicity effects on humans. One is that the toxicity is independent of the NPs, and could be realized by generating the active oxygen species (ROS) within the cells. Another is that the toxicity has a strong relationship with the chemical component of NPs. Recently, the U.S. Department of Agriculture and Food and Drug Administration (FDA), and the EU, conducted a brief assessment on NPs and nanomaterials applied in various areas of industry. The relatively scarce scientific data on migration, exposure sources and toxicities indicate the difficulties and problems in properly understanding the nature of NPs. Therefore, in order to fully assess the safety of NPs in food packaging the relationship between particle size, purity and toxicity has to be fully established.

## Conclusion

Nanotechnology has great potential to positively impact the food sector through improvement of existing products and development of new ones. Future development of agro and food industries will benefit from advances of nanotechnology which will increase soil fertility and improve crop quality and production, develop new improved multifunctional materials and healthy foods from agro resources and improve encapsulation of flavors and vitamins, food processing and packaging. Since many foods consist of structures at the nanolevel which are critical to the texture of the foods and in turn to the acceptance by the consumer, among the future needs are systematic studies of the structure/texture of food materials including modeling/simulation, the impact of changing raw materials and the interplay between structure and nutrition. Since the same unique physical and chemical properties that make nanomaterials so attractive may be associated with their potentially toxic effects, fully understanding of the migration properties of NPs in composites and their toxicity has to be established.

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