

Applications of Nanotechnology in Food Processing, Packaging and Safety: An Outline

Monika Sharma

Senior Scientist, Dairy Processing Section, ICAR- National Dairy Research Institute, SRS, Bengaluru-560030, Karnataka, India

*Corresponding Author: sharma.monikaft@gmail.com

Introduction

Nanotechnology is a rapidly emerging technology that enables us to work with, manipulate, and create tools, materials, and structures at the molecular level—often atom by atom—into functional structures with nanometer dimensions. “Nano” usually refers to a size scale between 1 and 1000 nanometers (nm). Nanotechnology is the design, fabrication and utilization of materials, structures, devices and systems through control of matter on the nanometer length scale and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale in at least one dimension. Nanotechnology is based on the convergence of several disciplines ranging from chemistry, materials science, physics, biology and engineering.

The food industry is looking for new technologies to improve the nutritional value, shelf-life and traceability of food products, to reduce extent of preservatives, formulating foods with low sugar, fat and salt, food for geriatric nutrition, thereby maintaining food safety. Nanotechnology has the potential to affect the food production industry at almost every stage, through agriculture, storage and transport, manufacturing, packaging, and disposal. However, there are concerns related to ingestion of nanomaterials. The benefits must therefore be shown to greatly outweigh any risks, and a deep understanding of the products' effects on the body must be demonstrated.

Importance of Nanoscale: Unique Properties of nanoparticles

- Not only miniaturization but change in physical properties
- Laws of quantum physics
- Surface behaviour dominates bulk material behaviour
- Metals become harder, and ceramics become softer
- Stronger, more heat resistant, transparent
- Increased chemical resistance, reduced weight
- Different interactions with light/other radiation
- New electrical properties
- Novel biological properties

Fabrication of nanomaterials

Production of new nanomaterials is achieved through either a “top-down” or “bottom-up” approach. The “top-down” approach involves physically machining materials to a nanometre size range by employing processes such as

grinding, milling, etching and lithography. The “bottom-up” approach relies on the self-assembling properties of molecules under thermodynamic control to build supramolecular structures, microstructures and higher hierarchical structures to produce functional materials. Examples of self-assembled nanostructures in food include the organisation of casein micelles, the structures formed in protein-polysaccharide coacervates, and liposomes.

Observation at Nanoscale

- Scanning Tunnelling Microscope (STM)
- Atomic Force Microscope (AFM)
- Magnetic-resonance force microscope (MRFM)
- Assemblers

Nanotechnologies for Food processing and safety

Convergence of nanotechnology with other technologies is also leading to further innovations that are expected to make a major impact on production, processing, storage, transportation, traceability, safety and security of food. For example, integration of biotechnology, nanotechnology and information technology has opened up new opportunities for the development of nano-biosensors for the detection of pathogens and contaminants in food. This amalgamation of right technologies along with proper understanding of taste receptors and flavour perception, has led to the development of an “electronic tongue”. Indeed, the manipulation of substances so close to the molecular level has blurred the boundaries between a number of traditional food science disciplines and opened up ways for the development of new food textures, tastes and sensations.

One of the important aspects in application of nanotechnology in food processing revolves around development of nanostructured food ingredients and sustainable delivery systems for targeted nutrients and supplements. For this, a variety of processes are being utilised, including nano-emulsions, surfactant micelles, emulsion bilayers and reverse micelles. Some nano-micelle-based carriers for nutraceuticals and nutritional supplements such as benzoic acid, citric acid, and ascorbic acid, dietary supplements and functional food ingredients, such as vitamins A and E, α -lipoic acid, soybean isoflavones, β -carotene, lutein, omega-3 fatty acids, and coenzyme Q₁₀ have been formulated. However, the problem with most emulsions is that they are dependent on conditions - just as they spontaneously form under certain conditions, they can also spontaneously dissociate if the temperature or concentration changes too much - not very useful for a system which may need to remain

stable through various areas of the human digestive tract. Stabilization of some materials also requires addition of significant amounts of surfactant, or emulsifier, which has to be food-grade, and may adversely affect the taste or texture of the food. Recently, self-assembled nanotubes have been developed from hydrolysed milk protein -lactalbumin, which can offer a new naturally derived carrier for nanoencapsulation of nutrients, supplements and pharmaceuticals.

Nanotechnologies for Food packaging

The increasing urgency of environmental issues demands the development of biodegradable materials that match the properties of polymeric materials while maintaining equivalent costs. Natural biopolymers clearly have the upper hand over synthetic biodegradable polymers because they are sourced from renewable raw materials. Such polymers include naturally existing ones such as proteins, cellulose, starches and other polysaccharides, with or without modifications, and those synthesized chemically from naturally derived monomers such as lactic acid. Starch-based biodegradable polymers have great commercial potential for bioplastics, but some properties, such as brittleness, high gas permeability, low melt viscosity for further processing, etc., often limit their applications. Among the biodegradable synthetic polymers, (polylactic acid) (PLA) appears to be one of the most attractive for film applications in agriculture and as a packaging material, because of its good biodegradability and mechanical properties.

The problems associated with biodegradable polymers are threefold: performance, processing, and cost. Although these factors are somewhat interrelated, problems due to “performance and processing” are common to all biodegradable polymers in spite of their origin (Ray et. al., 2006). Polymer layered silicate (PLS) nanocomposite technology was first developed for automotive applications by Toyota researchers in the late 1980s and Toyota was the first company to commercialize these nanocomposites (nylon 6-clay nanocomposites). In the following years, PLS nanocomposites have attracted increasing interest as a means for improving properties of synthetic polymers. With only a small percentage of silicate content ($\leq 5\%$), the nanocomposites exhibit remarkable improvement in materials properties when compared with pristine polymer or conventional micro- and macro-composites. These improvements can include high modulus, increased strength and heat resistance, decreased moisture, and gas permeability and flammability. Nanocomposites possess benefits like better surface properties, low density, transparency and recyclability. These polymer nanocomposites have also been studied for food packaging applications including injection molded bottles for beverage or beer, coatings for paperboard juice cartons, and cast and blown films. Use of these nanocomposites for packaging with oxygen scavenging, reduced flavor scalping, increased heat resistance, and high gas

barrier properties has resulted in shelf-life of 3–5 years for packaged food (Sajilata et al., 2007).

Nanotechnology in Food Safety

In addition to food packaging, food preservation is also of great importance for the food industry. Food spoilage can be detected with so-called nanosensors, for example, an array of thousands of nanoparticles designed to fluoresce in different colors on contact with food pathogens. Taking into account the crucial importance of time in food microbiology, the main aim of nanosensors is to reduce the time for pathogen detection from days to hours or even minutes. Such nanosensors could be placed directly into the packaging material, where they would serve as an ‘electronic tongue’ or ‘noses’ by detecting chemicals released during food spoilage.

Conclusion

Nanotechnology is becoming increasingly important in the food sector. Promising results and applications are being developed in areas such as food processing, packaging, and safety. However, long-term studies are needed to assess the effects of manufactured nanoparticles and nanotubes that may interact freely with humans or the environment. Additionally, there should be a global regulatory body to oversee food nanotechnology.

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