# Nanotechnology: current uses and future applications in the food industry

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***Abstract***— Recent advances in nanoscience and nanotechnology intend new and innovative applications in the food industry. Nanotechnology exposed to be an efficient method in many fields, particularly the food industry and the area of functional foods. Though as is the circumstance with the growth of any novel food processing technology, food packaging material, or food ingredient, additional studies are needed to demonstrate the potential benefits of nanotechnologies and engineered nanomaterials designed for use in foods without adverse health effects. Nano emulsions display numerous advantages over conventional emulsions due to the small droplets size they contain: high optical clarity, excellent physical constancy against gravitational partition and droplet accumulation, and improved bioavailability of encapsulated materials, which make them suitable for food applications. Nano-encapsulation is the most significant favourable technologies having the possibility to ensnare bioactive chemicals. This review highlights the applications of current nanotechnology research in food technology and agriculture, including nano emulsion, nanocomposites, nano sensors, nano-encapsulation, food packaging, and propose future developments in the developing field of agriculture food nanotechnology. Also, an overview of nanostructured materials, and their current applications and future perspectives in food science are also presented.

**Keywords:** Nano emulsion, Nanocomposites, Nano sensor, Nano-encapsulation, Food packaging.

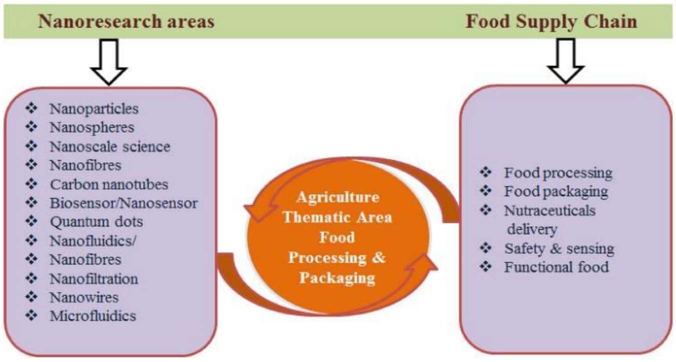
## 1) INTRODUCTION

Nanoscience and nanotechnology are innovative scientific advancements that have been introduced only in this century. Their utilizations in food and agriculture productions are almost modern compared with that of medicine delivery and pharmaceuticals. Nanotechnology has developed as the scientific advancement to grow and transform the entire agri food area, with the potential to elevate global food production, furthermore to the nutritional value, quality, and safety of food. Nanotechnology uses in food science are going to influence the most important aspects of food manufacturing from food protection to the molecular synthesis of new food products and ingredients. Nanotechnology is expected to facilitate the following development stage of genetically altered crops, input to the production of animal and fisheries, chemical insecticides and precision farming methods. Food endures a variability of post-harvest- and processing-persuaded changes that affect its biological and biochemical maquillage. Thus, nanotechnology development in the areas of biochemistry and biology could also affect the food manufacturing. There is a need to develop simpler, faster, more sensitive and low-cost approaches for the observation and quantification of impurities in foods. Within the past decade, with remarkable advances in nanoscience, nanotechnology-enabled sensors and systems have been increasingly used to develop rapid and non invasive methods of detection of food contaminants.

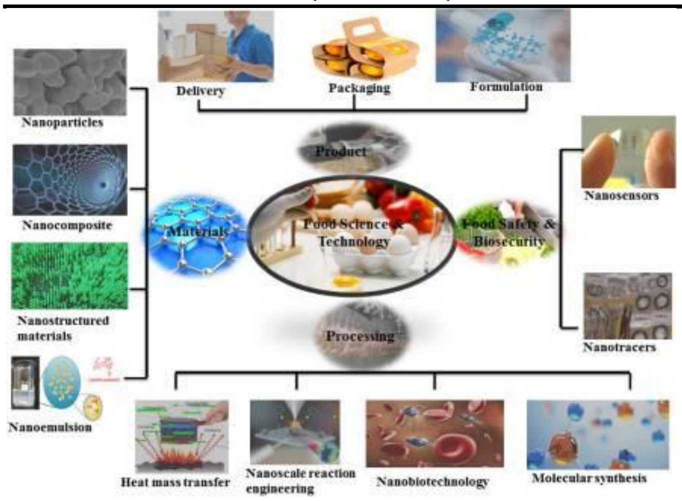
## 2)NANOTECHNOLOGY APPLICATIONS IN FOOD INDUSTRY

Nanotechnology has been reported as the new industrial revolution, both developed, and developing countries are investing in this technology to secure a market share. At present, the USA leads with a 4-year, 3.7-billion USD investment through its National Nanotechnology Initiative (NNI). The USA is followed by Japan and the European Union, which have both committed substantial funds (750 million and 1.2 billion, including individual country contributions, respectively, per year). Others such as India, South Korea, Iran, and Thailand are also catching up with a focus on applications specific to the economic growth and needs of their countries. Food processing approaches that involve nanomaterials include integration of nutraceuticals, gelation and viscosifying agents, nutrient propagation, mineral and vitamin fortification, and nano-encapsulation of flavours. Thus, systems with physical structures in the nano meter distance range could affect features from food safety to molecular synthesis. Nanotechnology may also have the potential to enhance food quality and safety. Many studies are assessing the ability of nano sensors to improve pathogen detection in food systems. Nanofoods are products that were grown processed or packaged with the aid of nanotechnology or materials produced with nanotechnology. In this review, we discuss some current nanotechnology research in food technology and agriculture, including processing, packaging, nano-additives, cleaning, and sensors for the detection of contaminants, and propose future developments in the developing field of agrifood nanotechnology .

Framework for integrating nano search areas and food supply chain




Different steps of food management that involve in several steps (processing, packing, preservation) and these are aided by nanotechnology



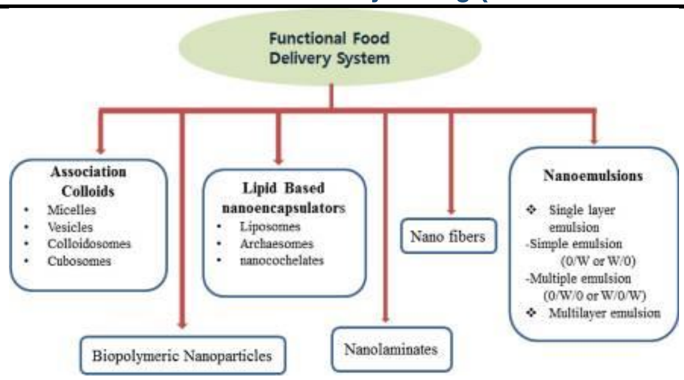

## 3)NANO-DELIVERY OF FOOD INGREDIENT

### NANOEMULSION

The emulsion is two or more combination of liquids (oil/water system) that do not simply combine. The diameters of nano emulsion to discrete droplets measure 500 nm or less. It can contain functional constituents within their droplets, which can ease a decrease in chemical degradation. When used in the food manufacturing nanotechnology needs to be reasonable, easy to utilize, and with willingly perceived benefits in order to be a real another to the normal techniques. There are diverse challenges like limited food-grade stabilizers or other ingredients obtainable. The food industry would like to prepare nano emulsions from legally acceptable, label-friendly, and economically viable ingredients. The most important is the toxicological concerns because the nano size of the droplets that could alter the normal function of the gastrointestinal tract

Nano emulsions have some potential benefits over traditional emulsions for specific uses within food and beverage products. Various types of nano emulsions with more complex properties, e.g., nanostructured multilayer emulsions or uncountable emulsions, produce various encapsulating skills from a single delivery system; this can promote the activity of the active components and facilitate their release in response to an activator. For example, Nestle and Unilever have developed a nano emulsion-based ice cream with less content of fat. Nano-encapsulation of food ingredients and additives had been carried out to provide protecting hurdles, taste and flavour masking, controlled release, and better dispensability for water-insoluble food ingredients and additives. There is a developing public concern regarding the toxicity and adverse effect of nanoparticles on human health and environment.

Lipid-based nano emulsions are better for the delivery of constituents within biological systems than traditional nano emulsions. However, the high lipid content of these nano emulsions results in adverse effects on the body, such as obesity and cardiovascular diseases Some approaches for forming nano emulsions using low-energy methods require the presence of cosolvents (e.g., polyols, such as propylene glycol, glycerol, and sorbitol) or cosurfactants (e.g., short and medium-chain alcohols). Nano emulsions present numerous benefits such as cleansing of equipment and high clearness without compromising product presence and flavour (Fig. 3). The use of nano emulsions to food systems still poses challenges that need to be addressed both concerning the production process, particularly their price and of the characterization of both the resultant nano emulsions and the food systems to which they will be applied to product safety and acceptance.




## 4)NANO-ENCAPSULATION

Nanotechnology can also facilitate encapsulation of drugs or other components for protection against environmental factors and can be used in the plan of food ingredients, e.g., flavours and antioxidants. Micro-encapsulation is used to increase bioavailability, control release kinetics, minimize drug side effects, and cover the bitter taste of medicinal substances in the pharmaceutical industry. In the food industry, nano emulsions are used in the organized release of additives and the manufacturing of foods containing functional constituents, such as probiotics and bioactive ingredients. Currently, numerous techniques of nano-encapsulation are progressively rising with their own merits and demerits. Moreover, solvent evaporation and nanoprecipitation remain to be particular techniques for encapsulation of lipophilic bioactive compounds. However, all the encapsulation technologies, in the long run, depend on proper drying strategies to provide nano encapsulates in powder form. Nano-encapsulation of valuable microorganisms, e.g., probiotics, is advantageous because targeted and site-specific delivery to the desired region of the gastrointestinal tract can be achieved. These nano-encapsulated designer bacterial preparations can be used in vaccine preparation and to enhance the immune response. Most nano encapsulates have shown excellent bioavailability, and few encapsulates have reported good inhibitory effect against certain targeted diseases. Moreover, the regulatory issues on nanofoods are still being developed, and it is expected that national bodies will increase initiatives to control, administrate, and promote the proper development of nano-sized food-related products.

## 5)PACKAGING OF FOOD ITEMS

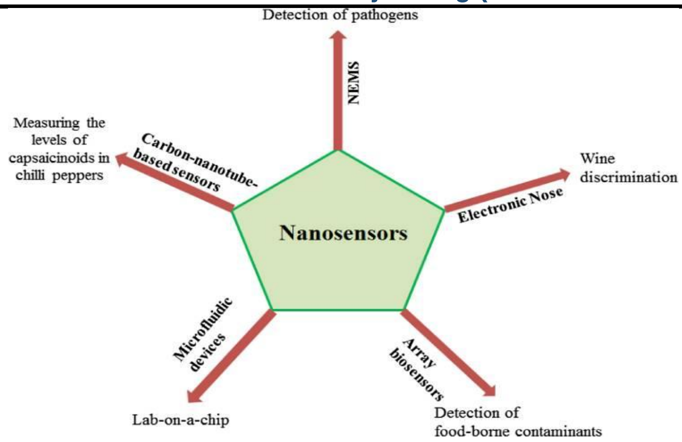
### NANOCOMPOSITES

Nanocomposites are mostly exploited in the area of food packaging, as they are eco-friendly and biodegradable. Nanocomposites exhibit extremely multipurpose chemical functionality and are therefore used for the growth of high obstacle properties. A nanocomposite-based commercialized fertilizer, Guard IN Fresh, helps fruits and vegetables to ripen by scavenging ethylene gas. Nano clays are made of aluminium silicates, commonly mentioned to as phyllosilicates, and are low-cost, constant, and eco-friendly. The nanocomposite is a multiphase material resulted from the combination of two or more constituents, containing a continuous phase (matrix) and a discontinuous nano-dimensional phase with at least one nano-sized dimension (with less than 100 nm). The development of bio-nanocomposite materials for food packaging is significant not only to reduce the environmental problem, but also to improve the functions of the food packaging materials. Moreover, nanoparticles could impart as their active or intelligent properties to food packaging so that they can preserve the food against external factors and increase the food's stability through antimicrobial properties and/or responding to environmental changes. The usage of nanocomposites for food packaging defends not only food, but also develops the shelf-life of food products and overcomes environmental problems associated with the use of plastics.

Shankar and Rhim (2016) produced nanocomposite films including PBAT (polybutylene adipate-co-terephthalate) and silver nanoparticles. The maximum plasmonic absorption of silver nanoparticles was detected at 435 nm. Moreover, the dramatic increase in tensile strength and water vapor permeability of the film was attributed to the presence of silver nanoparticles. Altogether, the formulated nanocomposite presented important features to be applied in packaging materials due to their UV-screening and biocidal activities. Better use of polymer–nanocomposite in the industry in Europe is going very slowly. The main reasons are the cost price of materials and processing, restrictions due to legislation, acceptance by customers in the market, lack of knowledge about the effectiveness and influence of nanoparticles on the ecological and on human health. In addition, this property increases the surface reactivity of the nano-sized antimicrobial agents compared to the bulk counterpart, making them able to kill microorganisms.

## NANOSENSORS

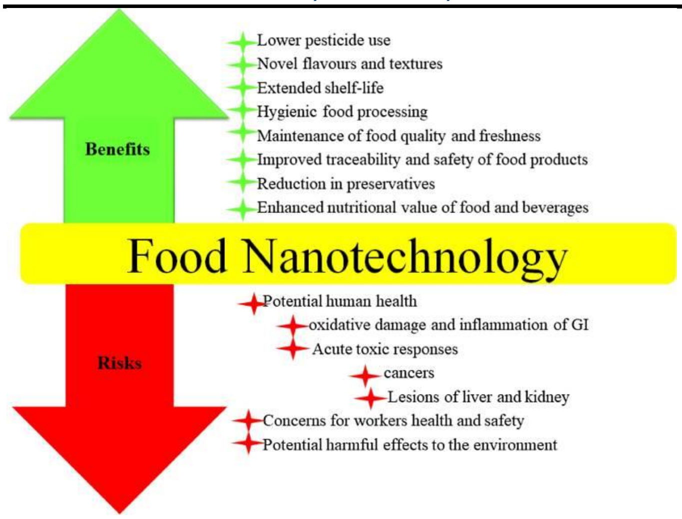
Nano sensors in conjunction with polymers are used to screen food pathogens and chemicals during storage and transit processes in smart packaging. Additionally, smart packaging confirms the integrity of the food package and authenticity of the food product. Nano-gas sensors, nano-smart dust can be used to detect environmental pollution. These sensors are composed of compact wireless sensors and transponders. Nano barcodes are also an efficient mechanism for detection of the quality of agricultural fields. An electrochemical glucose biosensor was nanofabricated by layer-by-layer self-assembly of polyelectrolyte for detection and quantification of glucose. Nano sensors can detect environmental changes, for example, temperature, humidity, and gas composition, as well as metabolites from microbial growth and by-products from food degradation. The types of nano sensors used for this purpose include array biosensors, carbon nanotube-based sensors, electronic tongue or nose, microfluidic devices, and nanoelectromechanical systems technology. The combination of nano sensors into food packaging has shown in various benefits than traditional sensors for example speed of analysis, enhanced sensitivity, specificity and multiplex systems (sample throughput), reduced cost and assay complexity. The sensors based on nanomaterials (nano sensor), both chemical sensors (chemical nano sensors) and biosensors (nano biosensors), can be used online and combined into existing industrial process and distribution line or off-line as speedy, simple, and transportable, as well as disposable, sensors for food contaminants.




Nano sensors can also be used to determine the qualities of various foods, including wine, coffee, juice, and milk. The sensors are designed using layer-by-layer macromolecule ultra-thin films that show increases in surface area and 10,000-fold higher sensitivity than the human tongue. Nano sensors can further be fixed to packaging to identify microorganisms contaminating food. The packaged food product does not need to be directed to the laboratory for sampling; instead, the sensors indicate the food quality and can be directly interpreted by consumers based on colour change. The use of nanoparticles to develop nano sensors for detection of food contaminant and pathogens in the food method is another possible use of nanotechnology. Nano sensors have also been applied for detection of organophosphates in plants, fruits, and water. Owing to the high water solubility, toxicity, and extensive use of pesticides in agriculture, there is an urgent requirement for highly sensitive and selective analytical systems for residue analysis of these pollutants. Nano sensors and nano-based smart delivery methods are the uses of nanotechnology that are presently working in the agricultural production to help with fighting viruses and other crop pathogens, as well as to boost the effectiveness of agrochemicals at lower amount proportions. Taking advantage of nanotechnology, researchers are beginning to realize the promising future in the field of biological sensors in food detection.

## 6)BENEFITS OF NANOMATERIALS IN FOOD PACKING USERS

The biodegradability of a packaging material can be augmented by integrating inorganic elements, for example, mud, into the biopolymeric medium and can be measured with surfactants that are utilized for the alteration of the layered silicate. The use of inorganic elements also makes it possible for food packaging to have multiple functionalities, which could aid in the development of methods to deliver fragile micronutrients within edible capsules. Food packaging is thought to be the main application of nanotechnology in the food industry. Nanotechnology uses in the food manufacturing can be exploited to produce stronger tastes and colour quality or detect bacteria in packaging, and safety by growing the obstacle properties and holds great potential to offer benefits not just within food products, but also around food products.




## 7)APPLICATIONS OF NANOTECHNOLOGY IN FOOD AND BIOACTIVES

Archaeosomes are a type of microbial lipid membrane resistant to oxidation, chemical and enzymatic hydrolysis, low pH, high temperature, and the presence of bile salts due to the hostile living environment of Archaea microbes. Canham (2007) found that the milk protein α-lactalbumin in certain conditions can undergo self-assembly to form tubular nanostructures. Such tubes are thousands of nano-meters long, their diameter is 20 nm, and the inner cavity diameter is about 8 nm. In the presence of calcium ions, this mixture self-assembles into helical tubes. Nano cochleates resulting from soy and calcium have been found to be suitable for the nano-encapsulation of vitamins, omega-3 fatty acids, and lycopene without affecting the organoleptic properties of foods. Dairy products, beverages cereals, and bread are now supplemented with minerals, vitamins, bioactive peptides, probiotics, plant sterols, and antioxidants. Some of these active components are being added to foods as nanoparticles or particles of a few hundred nm in size.Nanoparticles are added to various foods to increase flow properties, colour, and stability during processing, or shelf-life. For example, aluminosilicate materials are typically used as anticaking agents in powdered processed foods, whereas anatase titanium dioxide is a normal food whitener and brightener additive employed in sweets, some cheeses, and sauces. The applications explored here were particularly chosen because they are the most likely nanofood products to be accepted by consumers in the short term. Thus, food nanotechnology is still young, and the future of this exciting field is still largely uncertain. Regardless of how applications of nanotechnology in the food sector are ultimately marketed, governed, or perceived by the public, it seems clear that the manipulation of matter on the nanoscale will continue to yield exciting and unforeseen products.

## 8)AGRICULTURE

Nanotechnology has used for alterations of the genetic structures of crop plants, thereby facilitating their improvement. Nano-fertilizers (nano-coated fertilizers, nano-sized nutrients, or carbon-based nanomaterials or engineered metal-oxide), and nano-pesticides (inorganic nanomaterials or nano-formulations of conventional active ingredients), may provide a targeted/controlled release of agrochemicals, aimed to obtain their fullest biological effectiveness without over-dosage. Smart delivery of foods, a fast specimen of biological and chemical impurity, bio-separation of proteins and nano-encapsulation of nutritional supplements are some of the new areas of nanotechnology for food and agriculture. Reduced biosynthesis of chlorophyll by magnetic nanoparticles of $Fe_3O_4$ induced a similar and statistically important decrease of chlorophyll and carotene levels of seedlings in sunflower.

Nano-sized calcium carbonate was prepared by reaction of sodium carbonate and calcium chloride by the reversed-phase microemulsion technique and then loaded with the pesticide validamycin. The loading efficiency, stability, sustained-release performance and excellent ecological compatibility of the substance, the system for its use may be prolonged to another hydrophilic pesticide. Moreover, as a vehicle for active materials (pesticides, fertilizers, or plant growth regulators), nanoparticles can also be synthesized through catalytic oxidation–reduction. Subsequent use of these materials would decrease the quantity of these active constituents in the environment and reduce the time through which the environment is exposed to the effects of the nanomaterials. Using nanotechnology to create new formulations has revealed significant potential in enlightening the efficiency and security of pesticides. The use of nanotechnology in plant pathology goals exact agricultural difficulties in plant–pathogen interactions and bring new ways for crop protection. Some potential applications of nanoscale science, engineering, and nanotechnology for agriculture, expressly designed to improve and to protect agronomic yields and crop production as well as to detect and remediate environmental pollutants, have been addressed with attention focused on emerging occupational risks in this field

## 9)CONCLUSIONS

In conclusion, nanotechnology has become progressively important in the food industry. Food innovation is observed as one of the sector areas in which nanotechnology will play a major part in the forthcoming. New and future innovation is nanotechnology that has exceptionally extraordinary property in food source chain (precision farming techniques, smart feed, enhancement of food texture and quality, bioavailability/nutrient values, packaging, label crop production and use of agrochemicals such as nano-pesticides, nano-fertilizers, and nano-herbicides) round the world agricultural sector. Nanofood packaging resources may widen nourishment life, upgrade food safety, prepared customers that food is sullied or destroyed, repair tears in packaging, and uniform release added substances to grow the life of the food in the package. To maintain leadership in food and food-processing industry, one must work with nanotechnology and nano bio-info in the future. The future belongs to new products and new processes with the goal to customize and personalize the products. Improving the safety and quality of food will be the first step. Finally, nanotechnology enables to change the existing food systems and processing to ensure products safety, creating a healthy food culture, and enhancing the nutritional quality of food.

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