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Application of Nanotechnology in Food Industry and Some of its Hazard Effect on Human Body: An Overview

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ABSTRACT

Nanotechnology is a relatively novel and unconventional applicable technique in the field of food science and technology. It appears to be a promising tool for food security and food sustainability. Nanotechnology is described as the "understanding and control of matter at dimensions of about 1–100 nm, where unique phenomena allow for new applications". The chemical, physical, and biological characteristics of materials at this size are significantly different from the properties of individual atoms and molecules or bulk matter. These modifications result in nanoscale materials with distinct mechanical, electrical, magnetic, and photonic characteristics. The ability to modify matter at the nanoscale can lead to a better knowledge of biological, physical, and chemical processes at this scale, as well as the development of novel materials, structures, systems, and technologies that take use of these new features. This review aims to shed light on the definition and important application of nanotechnology in food industry and also some of the hazards of nanoparticle on human body.

Keywords: Nanotechnology, nanoencapsulation, risk assessment of nanotechnology

INTRODUCTION

The term "Nanofood" refers to food items that have been introduced to consumers utilizing nanotechnology tools and processes and may contain a mix of nanoparticles in an acceptable range. The structure and characteristics of matter can be manipulated at the nanometric scale, which leads to the use of materials in new and interesting research domains where nanotechnology and biology are combining. Nanotechnology allows for the enhancement of food product quality by modifying the physiochemical properties of nano-sized constituents of food items (Abbas *et al*., 2009, Prakash *et al*., 2013).

The incorporation of useful components into food has long been a subject of study, nanotechnology has paved the path for developments such as nanoemulsions and nanocomposites (Avella *et al*., 2005). Fresh foods are no longer the sole purpose of food processing, production of healthier foods is also an important aspect, which has led to processed foods having micronutrients nowadays an element that has been proved to satisfy many consumers (Weiss *et al*., 2006). Food safety and quality are major concerns that must be addressed in their entirety when new technologies emerge in an effort to enhance food quality and safety. The use of nanotechnology into the food science and technology has resulted in the development of food with improved solubility, thermal stability, novelty, and bioavailability, these functions are all necessary for a healthier life (Semo *et al*., 2007). Agriculture nanotechnology is focusing on the different uses of nano-food science in terms of safety and packaging, among other things. Nanoparticles have a considerable influence on food manufacturing, packaging, and storage because of their unique physicochemical properties, which allow for the development of novel, high-performance materials (Scrinis & Lyons., 2007). The preservation of food may include food preparation via the application of convenient methods for consumer's satisfaction. Whatever the method used to preserve the food, it is recommended that the food's sensory and quality characteristics are not harmed and stay as complete as feasible. Some of the methods of food processing utilizing nanomaterials include the integration of nutraceuticals, vitamin and mineral fortification, nutrition delivery, viscosifying agents and flavour nanoencapsulation, which is the recent use of nanotechnology in the food industries (Huang *et al*., 2010).

The application of nanotechnology is at a diverse scale in food industry including food packaging, storage, and quality monitoring (Fig.1). Nanotechnology is also applied to create interactive food on demand, allowing consumers to consume

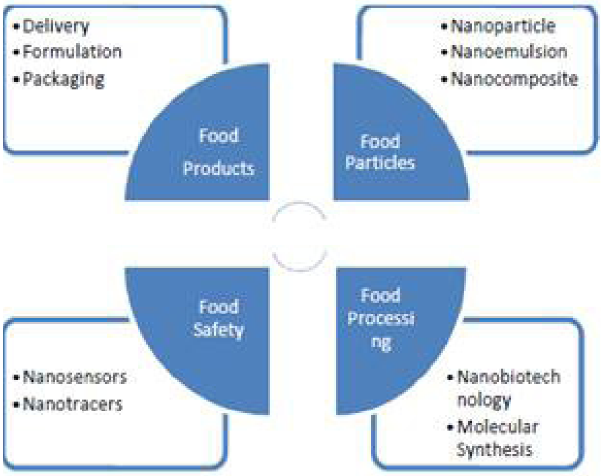

Fig. 1: Applications of Nanotechnology in various branches of food processing (Prakash *et al*., 2013)

modified food based on their nutritional requirements and preferences. Table (1) shows that there has been a rapid development in the application of nanotechnology in food processing industries. The major area of applications includes the alteration of food texture, food encapsulation, sensations and taste developments along with enhancing the bioavailability of the food nutrients. Even the league of food packaging has been enhanced by the usage of nanotechnology, which developed a new material with ameliorated barrier, antimicrobial and mechanical dominions (Prakash *et al*., 2013). The most recent nanotechnology applications in producing food include the creation of nano-sized food components, bioactive chemical delivery techniques, and novel food packaging (Ranjan *et al*., 2014). Nanoclays (NCs), nanoparticles (NPs), and nanoemulsions (NEs) are three types of nanomaterials (NMs) utilized in the agriculture and food industry. These may be synthesized in a number of methods and have a wide range of uses in the agricultural and food industries (Dasgupta *et al*., 2015)

Table 1: Various applications of nanobiotechnology in food science and engineering (Prakash *et al*. 2013)

Nanotechnology Applications	Benefits
Smart packaging	Improves barrier properties, flexibility, and temperature & moisture stability along with durability.
Nano – biosensors	Helpful to detect the spoilage of food products as well as contamination by the foreign particles.
Nano – encapsulations	Targeted delivery of nutrient and hence increased bioavailability of the nutrients.
Nano – biotracers	Useful to trace the food particles during shipment to long distances.
Nano – emulsions	Maintains the texture and appearance for a better consumer appeal.
Nano – composites	Maintains the structure of the food component and helps to keep the product at a steady sate which gives a better shelf life to the product.

Nanotechnology has a wide range of food industry applications, and it greatly aids in the characterization, manufacturing, and manipulation of nanostructures. The nanostructures increase the in-vivo solubility of food ingredients, as well as their bioavailability and controlled release at the target site. These nanostructures can also be used as anti-caking agents, nano-additives, nutraceutical delivery systems, and so on (Sahani & Sharm, 2021).

Food preservation and packaging

Food preservation refers to the treatment and processing of food to prevent the loss of its properties. Nanotechnology has implemented particular packaging sectors that have minimized environmental damage by using biodegradable packaging materials. Some of the topics that nanotechnology has addressed during packaging include the development of antimicrobials, high barrier polymers, and contamination detecting methods (Kang *et al*., 2007). Various nanosystems can be used as building blocks to create novel structures and increase the functionality of bioactive substances. These include nanoliposomes, nanoemulsions, nanocapsules (mostly biopolymeric), and nanofibers. Engineered nanoparticles used in food might be inorganic, surface-functionalized materials, or organic engineered nanoparticles. Polymer – clay nanocomposites (PCN) are another novel food packaging material. These are now used for packaging because of their light weight, high tensile strength, heat resistance, better barrier properties against oxygen, carbon dioxide, moisture, and ultraviolet light, as well as the ability to preserve the flavours in food and beverages (Moraru, *et al*., 2003, Chaudhry *et al*., 2008). Silver nanoparticles have been used as an antimicrobial food packaging material since antiquity. Historically, silver vessels were used to store and serve drinks, milk was also preserved with a spoon made of silver, and these practices were employed to extend the shelf life of foods and beverages. Silver was employed as a sterilizing agent for drinking water aboard NASA space shuttles and Russian MIR space stations. Later, the FDA changed the food additive laws to allow the direct inclusion of silver nitrate as a disinfectant to commercially accessible beverages packed in bottles at concentrations less than 17g/kg (FDA, 2009). This anti - microbial packaging slows the growth of microorganisms, keeping food safe for customer. It consists of antimicrobial nanomaterials layers between the packaging materials, or a sachet of antimicrobial nanoparticles in the packaging, or a bioactive agent coated on the surface of packaging materials that inhibits microbial growth (Coma, 2008). Food packaging techniques and procedures ensure that food quality is maintained and that it is safe to ingest. By eliminating oxygen and other gases that may cause food degradation, packaging protects food from external impact, temperature, and microbial infection. Traditional methods of food preservation include freezing, drying, and canning. However, nanotechnology has developed better and more reliable measures applicable in the methods of food preservation, such as the use of nanoparticle (Bouwmeester *et al*., 2009), nanosensors (Senturk *et al*., 2013, Su *et al*., 2013) and nanocomposites (Davis *et al*., 2013) in packaging. Inorganic nanostructures based on transition metals (such as silver and iron), metal oxides such as titanium dioxide, alkaline-earth metals (such as magnesium and calcium), nonmetals (as selenium), and silicates are examples of engineered nanoparticles which are mostly used in food packaging. Nano silver, which has antibacterial properties, is used in food and materials used in food packaging and nano selenium is used as an ingredient in green tea-based goods (Sekhon, 2010, Kuswandi, 2017).

The ongoing concern about the harmful effects of some artificial preservatives and antioxidants on consumer health have prompted interest in using natural compounds/products that can improve food shelf-life without harming health status. As a result, the discovery and application of natural antimicrobials and antioxidants, such as those found in extracts of plant or essential oils, as well as their classification based on safety, specificity, and effectiveness, as well as the application of effective delivery systems, are critical goals for the pharmaceutical and food industries .Many studies are being conducted to identify and apply suitable carriers for antibacterial compounds/products and antioxidants utilized in the food and pharmaceuticals industries (Pisoschi *et al*., 2016, Suganya & Anuradha, 2017, Pisoschi *et al*., 2018).

Nano – encapsulations

Surface modification of nanoparticles is important for various applications in food processing. The surface can be modified by coating or encapsulation of these nanoparticles. This is found to be applied in controlled release of genes, drugs, nutraceuticals, and various bioactive agents. This controlled release mechanism protects the particle from immediate degradation, controls the release rate, targets the delivery point, and prolongs the active duration of nutraceuticals and other bioactive agents (Chang *et al*., 1994, Cohen *et al.,* 2000, Zhang & Gao 2009). While microparticles possess a diameter ranging from 3 to 800 mm, nanoparticles possess diameters comprised between 0 and 1000 nm (in the colloidal range) and can be found as nanocapsules or as nanospheres (Gouin, 2004, Konan *et al*., 2002& Meena, *et al.,* 2011). Natural bioactive substances are chemically unstable and easily degraded by oxidation, which can compromise the compound (s)' integrity and contribute to the generation of free radicals .As a result, disagreeable flavours develop in the finished product, which has a detrimental impact on storage period, sensory properties, and consumers acceptance for and of the product (Rice-Evans, 1995, Meena *et al*., 2011, Ariyarathna & Karunaratne, 2015). Nanocapsules promote preservation of food by encapsulating odours and other undesirable components in food and delivering the component to the target. The capacity of a nanocapsule to convey its component which in this situation is the dietary supplement, through the stomach assures the component's bioavailability. It may also be used to transport lipophilic health supplements, vitamins, and minerals into meals. As a result, the nutritious content of the food is increased. Encapsulation guarantees that the concealed component navigates even in adverse situations in order to be delivered to the destination (Dreher, 2004).

The food manufacturing method aided by nanocapsules has many advantages: it is simple to operate, enhance stability, reduces or prevents oxidation, has the ability to maintain highly volatile ingredients, improves flavours, has a moisture-triggered control release, continuous delivery of several active compounds, pH-triggered controlled release, its sensory properties perception lasts longer, and has enhanced bioavailability (Chaudhry *et al*., 2008). Encapsulation has been used as a feasible strategy for the goals of storing and delivering naturally generated bioactive molecules at the appropriate time to selected areas in order to keep the quality or increase the biological utilization of these compounds. Encapsulation also is becoming increasingly popular in the pharmaceutical not only food industries. Small quantities of core material are encased in an exterior substance, resulting in particles containing bioactive components such as antioxidants (mostly phenolics and antioxidant enzymes), micronutrients and nutraceuticals to increase solubility, prevent decomposition, reduce toxicity, and regulate absorption and biological response. (Ezhilarsi *et al*., 2013, Conte *et al*., 2016, Wen *et al*., 2017). Moreover, the application of pure bioactive chemicals in biological compositions is limited owing to unfavourable qualities such as low aqueous solubility, poor bioavailability, and reduced stability in the presence of environmental variables such as pH, high temperature, oxygen and light exposure, so that protection from environmental aggressive factors and controlled release are achieved by encapsulation (Orellana-Palma *et al*., 2017, Shishir *et al*., 2018, Vaiserman *et al*., 2020).

Concerns have been raised about oxidative deterioration and microbiological decomposition, both of which are hazardous to human health. Natural antioxidants and antimicrobials reduce the toxicity of artificial chemicals., but they require proper delivery methods. Colloids-based nanostructures, nanoliposomes, nanoemulsions, nanofibers and nanocomposites are all possible. The following nanoencapsulation methods (Fig .2) are described for antimicrobials and antioxidants: association colloid-based nanoincorporation, lipid-based nanoencapsulation techniques, encapsulation techniques based on biologically-derived polymeric nanocarriers, cyclodextrin incorporation, electrospraying and electrospinning, carbon nanotubes, and nanocomposite encapsulation. Freeze-drying or spray-drying can be used after a variety of nanoencapsulation processes (Zorzi *et al*., 2015).

Nanosensors

The "Nano biosensor" is one of the greatest instances of technology integration for the benefit of the food industry. It was made feasible by the combination of bioengineering, nanotechnology, and software engineering. Nanosensors, electronic tongues, and bacteria identification are some of the most common applications of nanobiotechnology in food quality monitoring (Prakash *et al*., 2013). An electronic tongue has been developed which is included in food packaging and comprises of nanosensors. These are extremely sensitive to gases released by food during spoilage and the sensor strip changes color, signaling the freshness of food products (Ruengruglikil *et al*., 2004). By tracking food pollutants across the food production chain, nanosensors may provide quality assurance. The nanosensors may be used to precisely identify the presence of insects or fungus within stored grain bulk in storage rooms. Furthermore, because of their low power consumption and tiny size, nanosensors may be put in grain bulk cracks, where pests frequently hide (Neethirajan & Jayas, 2007). The Canadian Wheat Board Centre for Grain Research, University of Manitoba, Canada, has developed a grain quality monitoring nanosensors, which consists of nanoparticles polymers responding to analytes and volatile compounds in the food preservation environment, detecting the source and type of spoilage. Nanosensors aid in terms of detection of minor color changes in food in addition to gas produced by rotting. Furthermore, nanosensors are more sensitive and selective to these changes than standard sensor methods, making them more

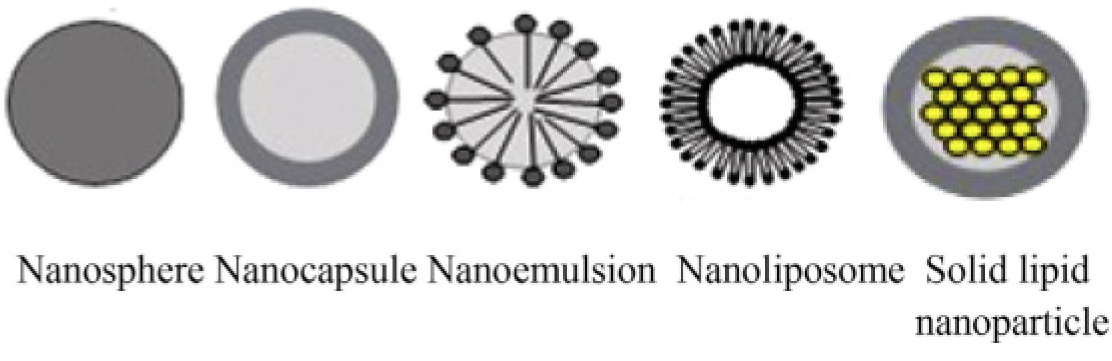

Fig. 2: The most common nanostructures used in antioxidant and antibacterial nanoencapsulation (Zorzi *et al*., 2015)

efficient (Mannino & Scampicchio, 2007, Neethirajan *et al.,* 2009). Gold, platinum, and palladium are used to make the gas sensors. The gold-based nanoparticles can detect the poison aflatoxin B1 present in milk. In certain cases, the packaging is made of DNA and single-walled carbon nanotubes, which significantly enhances sensor sensitivity. Nanosensors that detect pesticides on the surface of plants and fruits have the potential to help agriculture. Some nanosensors have also been utilized in the detection of carcinogens in food (Mao *et al*., 2006, Meetoo, 2011).

Nanoemulsions

A nanoemulsion is a kinetically stabilized dispersion of two or more insoluble fluids with droplet diameters of 50 to 1000 nm. Nanoemulsions are ultrafine oil-in-water emulsions with droplet sizes ranging from 50 to 200 nanometers. They do not scatter visible light and are thus transparent; also, because of their tiny particle size, these nanoemulsions stay stable for long periods of time. Figure (3) demonstrate the nanoemulsion formation. Nanoemulsions can be used in the manufacture of food items such as sweeteners, flavoured oils, salad dressing drinks, and other processed foods. The procedure involves the emergence of various tastes together with various stimuli as in heat, pH, ultrasonic waves, and many more. They effectively preserve the properties and safeguard them against enzymatic reactions and degradation (Kumar, 2000, Sanguansri & Augustin, 2006). Nanoemulsions have numerous benefits over traditional emulsions, including the fact that they are more heat - stable and have a smaller size. Nanoemulsions have the ability to interact with a wide range of biological substances such as enzymes in the gastrointestinal tract (GIT). For example, lipase readily digests the smaller droplets of nanoemulsions in GIT. Furthermore, nanoemulsions containing carbohydrates or proteins have improved the texture, which assists in the consistency of ice cream (Hogan *et al*., 2001, Zarif, 2003). Gu *et al*. (2005) created a nano-structured multilayer emulsion in multilayer membrane surface of dispersed oil droplets that is stabilized by beta-lactoglobulin, iota-carrageenan, and gelatin, and they have successfully applied nanoemulsions to drinking water and milk fortified with vitamins, minerals, and antioxidants. These functional components are incorporated without affecting the sensory properties of the products, while also allowing for the controlled release of bioactive components (Sanguansri & Augustin, 2006). Nanoemulsions can significantly enhance the bioavailability of lipophilic compounds. They have been used in parenteral nutrition for some time, even at low oil concentrations, they have distinct textural qualities, and the consistency of a viscous cream, making them suitable for the development of low-fat products (Padua & Nonthanum, 2012). Nanoemulsions have long been recognized to include antimicrobial compounds that are more effective against Gram-positive bacteria. As a result, nanoemulsions have been utilized to decontaminate materials used in food packaging (Wang *et al*., 2012). Nanoemulsions based on tributyl phosphate, soybean, or nonionic surfactants have been utilized to inhibit growth of microorganisms, therefore de-

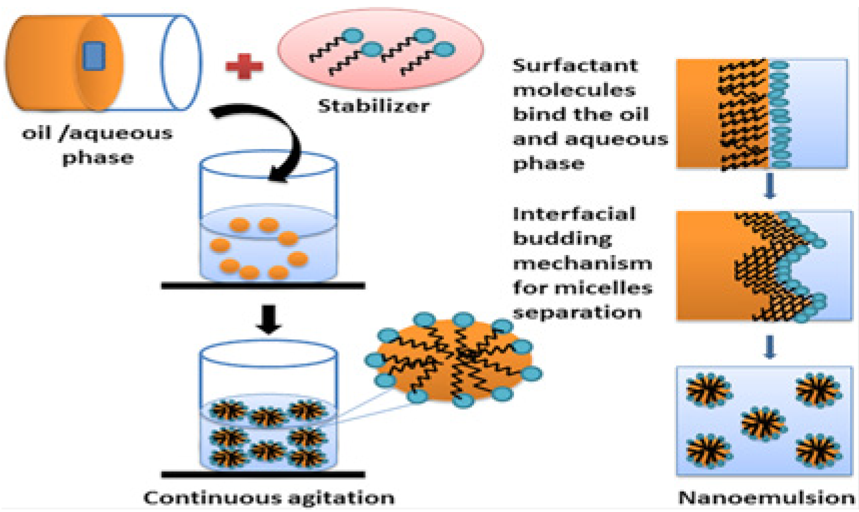

Fig. 3: Schematic demonstration of nanoemulsion formation (Sahani & Sharm, 2021)

creasing food deterioration (Sanguansri & Augustin, 2006).

Risk assessment of nanotechnology and effect of nanoparticles on human health

Nanotechnology may be used to produce packages with improved mechanical and thermal properties, and nanosensors might be integrated into packaging systems to notify customers when a food product is no longer safe to ingest .There have only been a few research that studied nanostructured materials in the intestinal system, and the findings of this study revealed that nanoparticles travel through the intestines and are swiftly excreted. In the public view, nanotechnology packaging is regarded as less troublesome. Consumers may be more willing to adopt packaging improvements than food innovations. The two aspects that most influence individual perceptions of nanotechnology utilized in food have been classified as nano-outside (e.g., packaging) and nano-inside (e.g., food) (Oberdörster *et al*., 2004, Scheufele & Lewenstein 2005, Sorrentino *et al*., 2007). The processing of food components to produce nanoparticulate food items may cause unneeded and detrimental changes in the physiological state of animals. The nanoparticle may readily penetrate the gut wall, increasing bioavailability and absorption and resulting in greater plasma concentrations. This may implicate a higher risk of diseases, due to change in the nutrient profile of the body or due to introduction of foreign particles in the blood as a dietary supplement in food products. Nanoparticles cannot remain in free form in the gut but it aggregates or agglomerates. This may also prove harmful for the physiology of human body (Chen & Mikecz 2005) . According to the findings of certain research, nanotechnology packaging is thought to be more helpful and poses less of a health danger than nanotechnology foods (Siegrist *et al*., 2007). Food and drinks are among the most common causes of animal illness. Since the increased uses of nanotechnology in food processing industries, there has been a rise in study efforts to identify possible hazards associated with the use of nanomaterials in food processing industries, as well as the toxicity of nano meals. Till now, the researchers are mainly inclined to the inhalation exposure of the nanomaterials. These research works have led to the fact that the nanoparticles can cross the cellular barriers, and the exposure to these nanoparticles leads to an exaggerated population of free radicals and hence the increased oxidative damage to the cell (Donaldson *et al*., 2004; Oberdorster *et al*., 2004, Prakash *et al*., 2013)

Nanotechnology might potentially be utilized to create healthier foods. In contrast to the well-documented benefits and prospective applications of engineered nanotechnology materials (ENMs), there is a lack of information on the possible (eco) toxicological consequences of nanoparticles (Savolainen *et al*., 2010). This is one of the factors why there are so many worries about the effects of nanoparticles on environmental and human health. ENMs contain a wide range of substances, in a variety of shapes and sizes, with a wide range of surface coatings, so it is critical in order to determine their presence and concentration not only in bulk samples, but also in workspace air, as this is one of the primary pathways for nanoparticles to reach the body. When considering the risk of nanoparticle exposure, several variables should be considered, including size and shape, bioactivity and crystal structures and purity (Savolainen *et al*., 2010 , Aschberger *et al*., 2011, Baltic *et al*., 2013).

Nanoparticles produced from engineered or other nanomaterials can go into the body by breathing, digestion, or skin entry. Nanotechnology-based medical devices, as well as medication injection and implant release, may be another avenue for nanoparticles. In the food sector, respiration and skin penetration are virtually solely associated with workers in nanomaterials manufacturing plants, while the major source of worry for end consumers is ingestion. The liver and spleen are the two primary organs for nanoparticle dispersion following intake and passage from the intestines to circulation (Aschberger *et al*., 2011, Silvestre *et al*., 2011, Baltic *et al*., 2013). The presence of nanoparticles in food is mostly due to direct interaction between nanopackaging and food, as well as migration of nanoparticles from nanopackaging materials (Bouwmeester *et al*., 2009, Baltic *et al*., 2013). In contrast to eating as a route of nanoparticle entrance, breathing and skin exposure have received greater attention. Elder *et al*. (2009) demonstrated that magnesium oxide nanoparticles breathed may enter the olfactory bundle under the forebrain via the axons of the olfactory nerve in the nose and can also reach other parts of the brain via systemic inhalation. The effect of nanoparticles on the human body is also determined by the characteristics of the nanomaterials. It has been shown in an *in vitro* study on human epithelial cell cultures that a nanoparticle can enter into the cell nuclei and leads to impairment of DNA replication as well as transcription. The study was performed using SiO_2 nanoparticles, which is generally used as a food additive and also in food packaging. It may lead to similar effects *in vivo* as previously reported (Chaudhry *et al*., 2008, Ramalingam *et al*., 2013).

Data of Baltic *et al.* (2013) demonstrated that when nanoparticles are hydrophilic and have a positively charged surface, the circulation time rises dramatically .The impact of nanoparticles on circulation has not been well studied, although preliminary findings suggest that these nanoparticles may have an adverse effect on bloodstream, particularly microcirculation. Particles that reach the circulation may have an influence on the lining of a blood artery or its function, encouraging the formation of blood clots, or may be connected to cardiovascular consequences from breathing ambient ultrafine particles. The perceived danger and advantages of nanotechnology foodstuffs and food packaging were significantly influenced by the significance of naturalness in food items and trust. Past surveys showed that the public is not familiar with the term nanotechnology (Pekkanen *et al*., 2002, Scheufele & Lewenstein 2005).

REFERENCES

Abbas, K.A., Saleh, A.M., Mohamed, A. & Mohd, A.N. **2009**. The recent advances in the nanotechnology and its applications in food processing: a review. Journal of Food Agriculture and Environmemt, **7**: 14–17.

Ariyarathna, I.R. & Karunaratne, D.N. **2015** .Use of chickpea protein for encapsulation of folate to enhance nutritional potency and stability. Food and Bioproduct Processing, **95**: 76–82.

Aschberger. K., Micheletti, C., Sokull-Klüttgen, B. & Christensen, F. M. **2011**. Analysis of currently available data for characterising the risk of engineered nanomaterials to the environment and human health—lessons learned from four case studies. Environment international, **37**:1143-56.

Avella, M., De Vlieger, J.J., Errico, M.E., Fischer, S., Vacca, P.& Volpe, M.G. **2005.** Biodegradable starch/clay nanocomposite films for food packaging applications. Food Chemistry, **93**: 467–474.

Baltic, Z.M., Boskovic, M., Ivanovic, J., Dokmanovic, M., Janjic, J., Loncina, J.& Baltic T.**2013**. Nanotechnology and its potential applications in meat industry. Tehnologija mesa, **54**:168-75.

Bouwmeester, H., Dekkers, S. & Noordam, M.Y. **2009**. Review of health safety aspects of nanotechnologies in food production. Regulatory Toxicology and Pharmacology, **53**: 52–62.

Chang,S.Y., Liu, L. & Asher.S.A. **1994**. Preparation and properties of Tailored morphology, monodisperse colloidal silica –cadmium sulphide nanocomposites. Journal of the American Chemical Society, **116**: 6739-6744.

Chaudhry, Q., Scotter, M., Blackburn, J., Ross, B., Boxall, A., Castle, L. &Watkins, R. **2008**.Applications and implications of nanotechnologies for the food sector. Food Additives & Contaminants, **25**: 241–258.

Chen, M.A & Mikecz.V. **2005**. Formation of nucleoplasmic protein aggregates impairs nuclear function in response to SiO_2 nanoparticles. Experimental Cell Research, **305**: 51 – 62.

Cohen, H., Levy, R.J., Gao, J., Kousaev, V., Sosnowski, S., Slomkowski, S. & Golomb,G. **2000**. Sustained delivery and expression of DNA encapsulated in polymeric nanoparticles. Gene Therapy, **7**: 1986.

Conte, R., Calarco, A., Napoletano, A., Valentino, A., Margarucci, S., Cristo, F., Salle, A. & Peluso, G. **2016**. Polyphenols nanoencapsulation for therapeutic applications. Journal of Biomolecular Research & Therapeutics, **5:** 1-13.

Coma, V. **2008**. Bioactive Packaging Technologies for Extended Shelf Life of Meat – Based Products. Meat Science, **78**: 90 – 103.

Dasgupta, N., Ranjan ,S., Mundekkad,D. ,Ramalingam ,C., Shanker ,R. & Kumar,A. **2015**. Nanotechnology in agro-food: From field to plate. Food Research International, **69**: 381–400.

Davis, D., Guo, X., Musavi, L., Lin, C.S., Chen, S.H. & Wu, V.C., **2013**. Gold nanoparticlemodified carbon electrode biosensor for the detection of Listeriamonocytogenes. Industerial Biotechnology. **9:** 31–36.

Donaldson, K., Stone, V., Tran, C. L., Kreyling, W. & Borm, P.J. **2004** Nanotoxicology. Occupational and Environmental Medicine, **619**: 727 – 8.

Dreher, K.L.**2004**. Health and environmental impact of nanotechnology: toxicological assessment of manufactured nanoparticles. Toxicological Sciences, **77**: 3–5.

Elder, A., Lynch, I., Grieger, K., Chan-Remillard, S., Gatti, A. & Gnewuch, H. **2009**. Human health risks of engineered nanomaterials: critical knowledge gaps in nanomaterials risk assessment. In: Nanomaterials: Risks and Benefits. Linkov, I., Steevens, J. (Eds.), Springer, Dordrecht,. p. 3– 29

Ezhilarasi, P. N., Karthik, P., Chhanwal, N. & Anandharamakrishnan, C. **2013**. Nanoencapsulation techniques for food bioactive components: A review. Food and Bioprocess Technology, **6**: 628–647.

Food and Drug Administration. **2009**. Federal Register, 74, 11476.

Gouin,S. **2004**. Microencapsulation: industrial appraisal of existing technologies and trends, Trends Food Scienc and Technology, **15**: 330-347.

Gu, Y.S., Decker, A.E. & McClements, D.J. **2005**. Production and characterization of oil-in-water emulsions containing droplets stabilized by multilayer membranes consisting of [beta]-lactoglobulin, [iota]-carrageenan and gelatin. Langmuir, **21**: 5752–5760.

Hogan, S.A., McNamee, B.F., O'Riordan, E.D.& O'Sullivan, M. **2001**. Microencapsulating properties of sodium caseinate. Journal of Agriculture and Food Chemistry, **49**: 1934–1938.

Huang, Q., Yu, H. & Ru, Q. **2010**. Bioavailability and delivery of nutraceuticals using nanotechnology. Journal of Food Science, **75**: 50–57.

Kang, S., Pinault, M., Pfefferle, L.D.& Elimelech, M. **2007**. Single-walled carbon nanotubes exhibit strong antimicrobial activity. Langmuir, **23**: 8670–8673.

Konan,Z.N., Gurny,R. & Allemann, E. **2002**. Preparation and characterization of sterile and freeze-dried sub-200 nm nanoparticles, International Journal of Pharmaceutics, **233**: 239-252

Kumar, M.N.R. **2000.** A review of chitin and chitosan applications. Reactive & Functional Polymers, **46**: 1–27.

Kuswandi,B. **2017**. Environmental friendly food nano-packaging. Environmental Chemistry Letters**, 15**: 205-221.

Mannino, S.& Scampicchio, M. **2007**. Nanotechnology and food quality control. Ethnoveterinary Health Management Practices, **31**: 149–151.

Mao, X., Huang, J., Fai Leung, M., Du, Z., Ma, L., Huang, Z.& Gu, L. **2006**. Novel coreshell nanoparticles and their application in high-capacity immobilization of enzymes. Applied Biochemistry and Biotechnology, **135**: 229–239.

Meena, K.S., Bairwa, N.K. & Parashar,B. **2011**. Formulation and in vitro evaluation of verapamil hydrochloride loaded microcapsule using different polymer, Asian Journal of Biochemical and Pharmaceutical Research, **7**: 528-538.

Meetoo, D.D. **2011**. Nanotechnology and the food sector: from the farm to the table. The Emirates Journal of Food and Agriculture, **23**: 387–407.

Moraru, C. I., Panchapakesan, C.P., Huang, Q.R., Takhistov, P., Liu, S. & Kokini, J.L. **2003**. Nanotechnology: A new frontier in food science. Food Technology, **57**: 24 – 29.

Neethirajan, S., & Jayas, D.S. **2007**. Sensors for grain storage. In: 2007 ASABE Annual International meeting, 17 – 20.

Neethirajan, S., Gordon, r., & Wang, L. **2009**. Potential of Silica bodies (phytoliths) for nanotechnology. Trends in Biotechnology, **27**: 461 – 467.

Oberdörster, G., Sharp, Z., Atudorei, V., Elder, A., Gelein, R., Kreyling, W.& Cox C. **2004**. Translocation of inhaled ultrafine particles to the brain. Inhalation Toxicology, **16**: 437–45.

Orellana-Palma, P., Petzold, G., Guerra-Valle, M.& Astudillo-Lagos, M. **2017**. Impact of block cryoconcentration on polyphenol retention in blueberry juice. Food Bioscience, **20**: 149–158.

Padua, G.W. & Nonthanum, P. **2012**. Material components for nanostructures. In: Nanotechnology Research Methods for Foods and Bio products, Padua, G.W. & Wang, Q. (Eds). JohnWiley & Sons, Inc., New Jersey, USA, pp. 5–18.

Pekkanen, J., Peters, A., Hoek, G., Tiittanen ,P., Brunekreef, B., de Hartog, J., Heinrich, J., Ibald-Mulli, A., Kreyling, W.G., Lanki, T., Timonen, K.L. & Vanninen, E. **2002.** Particulate air pollution and risk of ST-segment depression during repeated submaximal exercise tests among subjects with coronary heart disease: the Exposure and Risk Assessment for Fine and Ultrafine Particles in Ambient Air (ULTRA) study. Circulation, **106**: 933-38.

Pisoschi,A.M., Pop. A., Georgescu.C., Turcus.V., Olah,N.K. & Mathe, E. **2018**. An overview of natural antimicrobials role in food. European Journal of Medicinal Chemistry, **143**: 922-935.

Pisoschi,A.M., Pop,A., Cimpeanu,C. & Predoi,G. **2016**. Antioxidant capacity determination in plant and plant derived products: a review, Oxidative Medicine and Cellular Longevity, 9130976, 36 pages, https://doi.org/10.1155/2016/ 9130976.

Prakash, A., Sen, S. & Dixit,R. **2013**. The Emerging Usage and Applications of Nanotechnology in Food Processing Industries: The new age of nanofood. International Journal of Pharmaceutical Sciences Review and Research, **22**: 107-111

Ramalingam, C., Jain,H.; Vatsa,K., Akhtar,N., Mitra,B., Vishnudas,D., Yadav,S., Garg,K., Prakash,A. & Rai.A. **2013**. Detection and biochemical characterization of microorganisms in milk and cocoa powder samples by FTIR and subsequent production of bacteriocin from lactobacillus. International Journal of Drug Development and Research, **5**: 310 – 320.

Ranjan, S., Dasgupta, N., Chakraborty, A.R., Samuel, S.M., Chidambaram, R.& Rishi, S. **2014**. Nano science and nanotechnologies in food industries, opportunities and research trends. Journal of Nanoparticle Research,**16**:1-23

Rice-Evans, C. **1995**. Plant polyphenols: Free radical scavengers or chain-breaking antioxidants. Biochemical Society Symposia , **61**: 103–116.

Ruengruglikil, c., Kim, H., Miller, r.D., & Huang, Q. **2004**. Fabriction of nanoporous oligonucliotide microarrays for pathogen detection and identification. Polymer preprints, **45**: 526.

Sahani,S & Sharm, Y.C. **2021**. Advancements in applications of nanotechnology in global food industry. Food Chemistry, **342**: 128318.

Sanguansri, P. & Augustin, M.A. **2006.** Nanoscale materials development – a food industry perspective. Trends in Food Science and Technology, **17**: 547–556.

Savolainen. K., Alenius, H., Norppa, H., Pylkkänen, L., Tuomi, T.& Kasper, G. **2010**. Risk assessment of engineered nanomaterials and nanotechnologies: a review. Toxicology*,* **269**: 92–104.

Scheufele, D.A & Lewenstein, B.V. **2005**. The public and nanotechnology: How citizens make sense of emerging technologies. Journal of Nanoparticle Research , **7**: 659–67

Scrinis, G. & Lyons, K. **2007**. The emerging nano-corporate paradigm:Nanotechnology and the transformation of nature, food and Agri-food system. The International Journal of Sociology of Agriculture and Foods, **5**: 22 – 44.

Sekhon, B.S. **2010**. Food nanotechnology-an overview, Nanotechnol Light: Science and Applications, **3**: 1-15.

Semo, E., Kesselman, E., Danino, D.& Livney, Y.D. **2007**.Casein micelle as a natural nano-capsular vehicle for nutraceuticals. Food Hydrocolloids, **21**: 936–942.

Senturk, A., Yalcın, B. & Otles, S. **2013**. Nanotechnology as a food perspective. Journal of Nanomaterials & Molecular Nanotechnology, **2**: 2- 6.

Shishir, M.R.I., Xie, L., Sun, C., Zheng, X.& Chen,W. **2018**.Advances in micro and nano-encapsulation of bioactive compounds using biopolymer and lipid-based transporters. Trends in Food Science and Technology, **78**: 34–60.

Siegrist, M., Cousin, M.E., Kastenholz, H. & Wiek ,A. **2007**. Public acceptance of nanotechnology foods and food packaging: The influence of affect and trust. Appetite, **49**:459–66.

Silvestre, C., Duraccio, D. & Cimmino, S. **2011**. Food packaging based on polymer nanomaterials. Progress in Polymer Science, **36**: 1766–82.

Sorrentino. A., Gorrasi, G. & Vittoria, V. **2007**. Potential perspectives of bio-nano-composites for food packaging applications. Trends in Food Science and Technology, **18**: 84-95.

Su, H.C., Zhang, M., Bosze, W., Lim, J.H. & Myung, N.V. **2013**. Metal nanoparticles and DNA co-functionalized single-walled carbon nanotube gas sensors. Nanotechnology, **24**: 502-505.

Suganya, V. & Anuradha,V. **2017**. Microencapsulation and nanoencapsulation: a review. International Journal of Pharmaceutical and Clinical Research, **9**: 233-239.

Vaiserman, A., Koliada, A., Zayachkivska, A.& Lushchak, O. **2020**. Nanodelivery of natural antioxidants: An anti-aging perspective. Frontiers in Bioengineering and Biotechnology, **7**: 447-453.

Wang, Y., Zhang, Q., Zhang, C.L.& Li, P. **2012**. Characterisation and cooperative antimicrobial properties of chitosan/nano-ZnO composite nanofibrous membranes. Food Chemistry, **132**: 419–427.

Weiss, J., Takhistov, P. & McClements, D.J. **2006**. Functional materials in food nanotechnology. Journal of Food Science, **71:** 107–116

Wen, P., Zong, M.H., Linhardt, R.J., Feng, K. & Wu, H. **2017**. Electrospinning: A novel nanoencapsulation approach for bioactive compounds. Trends in Food Science Technology, **70**: 56–68.

Zarif, L. **2003**. Nanocochleate cylinders for oral & parenteral delivery of drugs. Journal of Liposome Research, **13**: 109–110.

Zhang, J.X. & Gao, L.Q. **2009**. Nanocomposites powders from coating with heterogeneous nucleation processing, Ceram. Int. 27, 2001, 143. Neethirajan, S., Gordon, r., & Wang, L. Potential of Silica bodies (phytoliths) for nanotechnology. Trends in Biotechnology, **27:** 461 – 467.

Zorzi,G.K., Carvalho,E.L.S., Lino von Poser,G. & Teixeira,H.F. **2015**. On the use of nanotechnology-based strategies for association of complex matrices from plant extracts, Revista Brasileira de Farmacognosi, **5**: 426-436.

استخدام تقنية النانو فى صناعة الغذاء وبعض مخاطر ذلك على جسم الإنسان: نظرة شاملة

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تقنية النانو هي تقنية جديدة وواعدة فى مجال علوم و صناعة الأغذية كما تعد مصدرا جديدا لتحقيق مزيد من الأمن الغذائي وإستدامة الغذاء. تعرف تقنية النانو بأنها «إمكانية فهم المادة والتحكم فيها بأبعاد تتراوح من ١ إلى ١٠٠ نانومتر ، حيث تسمح الأحجام الصغيرة بمزيد من التطبيقات الجديدة وغير التقليدية للمواد .» تختلف الخصائص الكيميائية والفيزيائية والحيوية للمواد بهذا الحجم اختلافًا كبيرًا عن خصائص الذرات والجزيئات الأصلية أو المادة الأساسية حيث ينتج عن هذه التعديلات مواد نانوية ذات خصائص ميكانيكية وكهربائية ومغناطيسية وفوتونية مميزة. أيضا يمكن أن تؤدي القدرة على تعديل المادة على المستوى النانوي إلى معرفة أفضل بالعمليات الحيوية والفيزيائية والكيميائية على هذا النطاق ، فضلاً عن تطوير مواد وهياكل وأنظمة وتقنيات جديدة باستخدم هذه المميزات الجديدة للمواد. تهدف هذه الدراسة المرجعية إلى إلقاء الضوء على تعريف تقنية النانو و أهم تطبيقاتها في مجال الصناعات الغذائية وكذلك إلقاء الضوء على بعض من مخاطر الجسيمات النانوية عند دخولها جسم الإنسان.