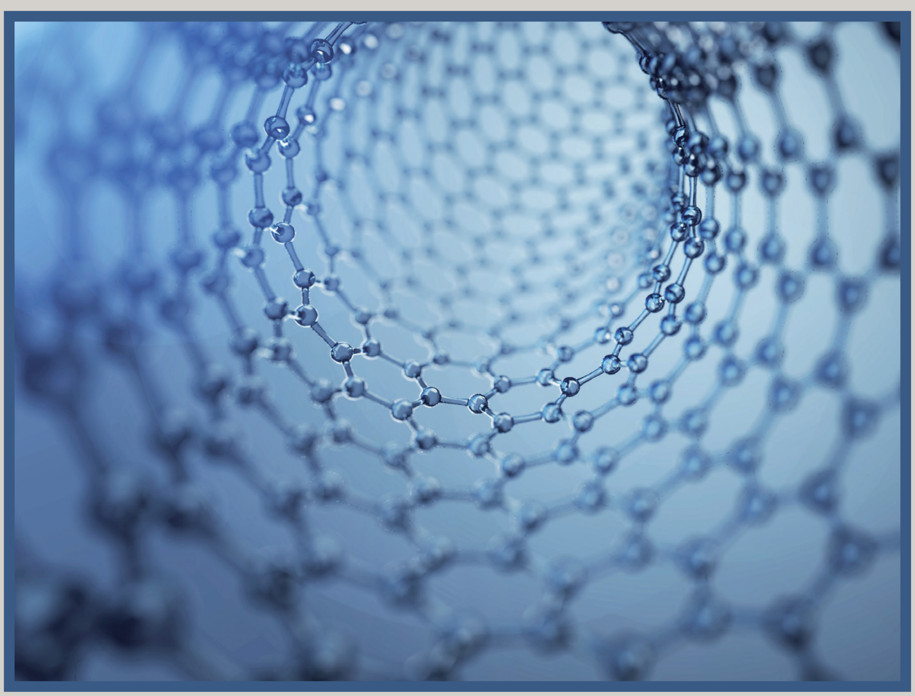
LISTED IN
SCIENCE CITATION INDEX EXPANDED
EMBASE
SCOPUS

MINERVA BIOTECNOLOGICA

A JOURNAL ON BIOTECHNOLOGY AND MOLECULAR BIOLOGY

VOLUME 30 · NO. 2 · JUNE 2018

PUBBLICAZIONE PERIODICA TRIMESTRALE - POSTE ITALIANE S.P.A. - SPED. IN A. P. D.L. 353/2003 (CONV. IN L. 27/02/2004 N° 46) ART. 1, COMMA 1, DCB/CN - ISSN 1120-4826 TAXE PERÇUE



EDIZIONI MINERVA MEDICA

Minerva Biotecnologica 2018 June;30(2):69-73
DOI: 10.23736/S1120-4826.18.02394-7

REVIEW

The role of nanotechnology in food safety

Carmela COLICA [1], Vincenzo AIELLO [2], Luigi BOCCUTO [3, 4], Nazarii KOBYLIAK [5], Maria C. STRONGOLI [6], Immacolata VECCHIO [6], Ludovico ABENAVOLI [7] *

[1]CNR, IBFM UOS of Germaneto, “Magna Graecia” University of Catanzaro, Catanzaro, Italy; [2]Department of Medical and Surgical Sciences, “Magna Graecia” University of Catanzaro, Catanzaro, Italy; [3]Greenwood Genetic Center, Greenwood, SC, USA; [4]Clemson University School of Health Research, Clemson, SC, USA; [5]Department of Endocrinology, Bogomolets National Medical University, Kiev, Ukraine; [6]CNR, ISN UOS of Roccelletta di Borgia, Complesso “Ninì Barbieri”, Catanzaro, Italy; [7]Department of Health Sciences, “Magna Graecia” University of Catanzaro, Catanzaro, Italy

*Corresponding author: Ludovico Abenavoli, Department of Health Sciences, “Magna Græcia” University, Viale Europa, 88100, Catanzaro, Italy.
E-mail: l.abenavoli@unicz.it

ABSTRACT

Nanotechnology is the engineering of functional systems at the molecular scale. Recently, nanotechnology are developed in the food area, with various applications, including improvements in nutrient and bioactive delivery systems, in texture and flavor encapsulation, in microbiological control, in food processing and packaging, and specific, highly sensitive biosensors that can be used to detect pathogens, allergens, contaminants, and degradants that can affect food quality and safety. Nanotechnology can also be used to design new food ingredients, such as solid-liquid particles, multilayered particles, fibers, assembled aggregates and novel structures using lipids, proteins, and other components that are present in natural food, and approved food ingredients. However, it is necessary to analyze the properties and characteristics of nanomaterials for potential health risks. The application of nanotechnology in the food production, packaging and storage, open new questions on the possible risks for the health of the consumers, and require a new and updated legislation to regulate the labeling and the presence in the food of these components.

(*Cite this article as:* Colica C, Aiello V, Boccuto L, Kobyliak N, Strongoli MC, Vecchio I, *et al.* The role of nanotechnology in food safety. Minerva Biotec 2018;30:69-73. DOI: 10.23736/S1120-4826.18.02394-7)

Key words: Nanostructures - Nanoparticles - Nutritional sciences - Food packaging - Health.

Nanotechnology, also known as “nanotech”, is the science of manipulating materials on an atomic or molecular scale, at dimensions between approximately 1 and 100 nm, that are known as the nano-scale, especially to build microscopic devices. Unusual physical, chemical, and biological properties can emerge in materials at the nano-scale. These properties may differ in important ways from the properties of bulk materials and single atoms or molecules.[1, 2] Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, energy, environmental science, medicine, pharmacy, homeland security, transportation and food safety among many others.[3, 4] Using nanotechnology, materials can effectively be made to be lighter, stronger, more reactive, more durable, more sieve-like, or better electrical conductors, among many other traits.[5] There already exist commercial products that rely on nanoscale materials and processes, and in particular: 1) in polymer composite materials can make them simultaneously lightweight, durable, and resilient; 2) in surface treatments of fabrics help them resist wrinkling, staining, and bacterial growth; 3) in food containers minimize carbon dioxide leakage out of carbonated beverages, or reduce oxygen inflow or the growth of bacteria in order to keep food fresher and safer; 4) into plastic packaging can warn against spoiled food; 5) detect salmonella, pesticides, and other contaminates on food before packaging and distribution; 6) finally, are used in cosmetic products like creams, lotions, shampoos, and specialized makeup.[5, 6]

Other nanotechnology applications in the food sector include altering the texture of food, encapsulating food components or additives and increasing the bioavailability of nutritional components.[7, 8] One of the major limiting factors is the availability of suitable analytical techniques to detect and to characterize engineered nanomaterials (ENMs) in food and beverage matrices. This may also prevent industry from rapidly developing ''nano-foods,'' since it is hard to assess how ENMs alter the properties of products. It is known that ENMs are highly reactive because of their high surface-to-volume ratio, meaning that they can interact with proteins, carbohydrates and fats in food, as well as nucleic acids, ions, minerals and water.[9] However the applications of nanotechnology in food and agricultural systems are growing very fast and there is a growing interest in this exciting research area. In the present review, we summarize the recent evidences on the application of nanotechnology in food safety and its potential perspectives.

Nanotechnology in food packaging

Recent innovations in nanotechnology have changed some scientific and industrial areas including the food sector (Figure 1). The applications of nanotechnology have emerged in various fields of food science, and includes a range of potential applications, as a alterations to the properties of foods, improvements to the delivery, quality, and safety of food, and the development of enhanced food packaging.[10, 11] Nanotechnology derived food packaging materials, are the largest category of current applications in food sector.[12] The developed food contact materials, now incorporate nanomaterials to improve packaging properties, as a flexibility, gas barrier properties, temperature stability, nanoparticles with antimicrobial or oxygen scavenging properties, nanosensors to monitor and report the condition of the food.[11, 12] A relatively low level of nanoparticle is sufficient to change the properties of packaging materials, without significant changes in density, transparency and processing characteristics.[12, 13] The polymer composites incorporating clay nanoparticles are among the first nanocomposites to emerge on the market and limit the permeation of gases, and provide substantial improvements in gas barrier properties.[14] Polymer nanocomposites incorporating metal or metal oxide nanoparticles have been developed for antimicrobial ''active'' packaging, abrasion resistance, UV absorption and/or strength.[14, 15] The metal and metal oxide nanomaterials commonly used are silver (Ag), gold (Au), zinc oxide (ZnO), silica (SiO_2), titanium dioxide (TiO_2), alumina (Al_2O_3) and iron oxides (Fe_3O_4, Fe_2O_3).[16] Based on the antimicrobial action of nanosilver, a number of active food contact materials have been developed that preserve the food materials within longer by inhibiting the growth of microorganisms.[17] Copper has been shown to be an efficient sensor for humidity, and titanium oxide has resistance to abrasion and UV-blocking performance.[18] Consequently, nanocomposites incorporate properties to the packaging material for enhance stability of foods, or at least to indicate their eventual inadequacy to be consumed. Moreover, the main risk of consumer exposure to nanoparticles from food packaging, is the potential migration of nanoparticles into food and drinks. The properties and safety of the materials in their bulk forms are usually well known, but the nano-sized counterparts frequently exhibit different properties from those found at the macro-scale. There are limited scientific data about migration of most types of nanoparticles from the packaging material into food, as well as their eventual toxicological effects. It is reasonable to assume that migration may occur, hence the need for accurate information on the effects of nanoparticles to human health following chronic exposure is imperative.[19]

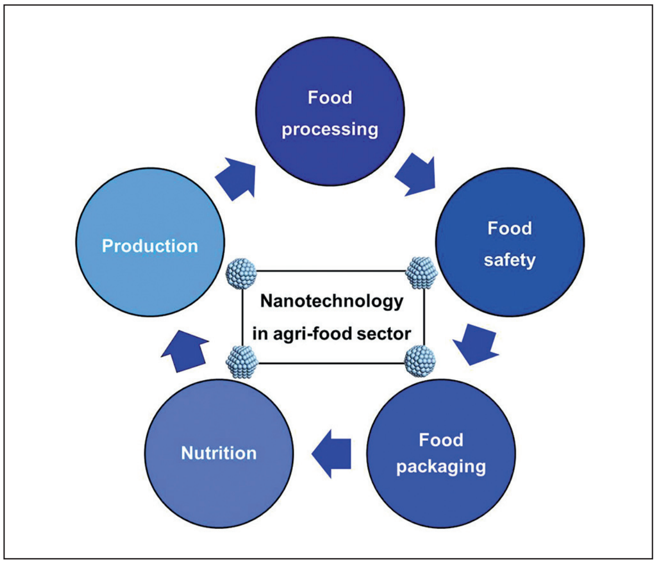


Figure 1.—Schematic application of nanotechnology in agri-food sector.

Nanotechnology in agrifood sector

Currently, nanoscale science, engineering and nanotechnology are implicated in agriculture and food production. Many researchers have studied the effects of nanomaterials on plant germination and growth with the goal to promote its use for agricultural applications.[20, 21] The effects of nano TiO_2 on the growth of naturally-aged spinach seeds were studied, and the plant dry weight was increased, as was the chlorophyll formation, the ribulose bisphosphate carboxylase/oxygenase activity, and the photosynthetic rate.[22] The key to increased seed germination rate is the penetration of nanomaterials into the seed. It was reported that multi-walled carbon nanotubes (MWCNTs) can penetrate tomato seeds and increase the germination rate by increasing the seed water uptake.[23] Other studies on the influence of metal nanoparticles on germination of lettuce seeds indicated that nanoparticles, and in particular ZnO, Pd and Au at low concentration, Si and Cu at higher concentration, and combination of Au and Cu, had a positive influence on seed germination, measured in terms of shoot to root ratio and growth of the seedling.[23] The increased biological efficiency of certain nanopesticides, could allow for diminished applications of conventional pesticides. Similarly, nanodevices used for "smart" treatment detect, locate, and report on pathogens, then apply pesticides and fertilizers as needed prior to the onset of symptoms.[24] US Environmental Protection Agency (EPA) observes that: "fertilizers and pesticides that incorporate nanotechnology may result in less agricultural and lawn/garden runoff of nitrogen, phosphorus, and toxic substances, which is potentially an important emerging application for nanotechnologies that can contribute to sustainability".[25] Smart nanosensors could be a viable option to detect pesticide residues in the field and also have been applied for pesticide degradation.[26] Nanoparticles can be also used as biomarkers or as a rapid diagnostic tool for detection of bacterial, viral and fungal plant pathogens.[27, 28] However, it is necessary to highlight that the balance of nanoparticles on plants can be positive or negative. One of the concerns for nanomaterials applications in seed germination, is their phytotoxicity. The level of phytotoxicity may depend on the type of nanomaterial and its potential application.[29] However, toxicity of nanosilver to ecosystem and human is a major concern; in fact there are more than 100 pesticides that contain Ag due to its anti-microbial properties. Was reported the cellular uptake, and toxic effects of silver nanomaterials to human skin keratinocyte cells and result that silver nanomaterials are aggregated inside the cell.[29, 30]

Food nanotechnology

Food nanotechnology is a combined discipline of nanotechnology and food science, that provides many applications almost in all areas of food technology. The three main constituents of food, proteins, carbohydrates and lipids, are each digested by different ways, that occurs at the nanoscale. On this basis, it could be hypothesized that the processing of foods at the nanoscale would simply improve the speed or efficiency of their digestion, uptake, bioavailability and metabolism in human body.[31, 32] The applications of nanotechnology and nanoparticles in food are emerging rapidly. The food industry is looking out for new technologies to improve the nutritional value, shelf-life and traceability of their food products.[7, 32] They are also aiming to develop improved tastes, reduce the amount of salt, sugar, fat and preservatives, address food-related illnesses as a obesity, diabetes, and blood hypertension, develop targeted nutrition for different lifestyles and aging population, and maintain sustainability of food production, processing and food safety.[8] Food processing can use nanotechnology in different ways: nanocapsules improve bioavailability of nutraceuticals in standard ingredients such as cooking oils; nanoencapsulated flavor enhancers refine the taste of food; nanotubes and nanoparticles can act as gelatin and viscosifying agents; nanocapsules infusion of plant-based sterols can replace meat cholesterol; and nanoemulsions and particles improve the availability and dispersion of nutrients.[7, 8] A variety of microencapsulated food ingredients and additives, as a vitamins, antimicrobials, antioxidants, probiotics, are available for use in a range of food products, and a recent trend in the health food area is microencapsulation of live probiotic microbes to promote healthy gut function.[33, 34] In nutrition research area, nanotechnology applications may assist with obtaining accurate spatial information about the location of a nutrient or bioactive food component in a cell, cellular component, and tissue.[7, 8] Ultrasensitive detection of nutrients and metabolites, as well as increasing an understanding of nutrient and biomolecular interactions in specific tissues, has become possible. In theory, such new technologies have the potential to improve nutritional assessment and measures of bioavailability. They may help to identify and characterize molecular targets of nutrient activity and biomarkers of effect, exposure, and susceptibility and therefore may also be the carriers of a "personalized" nutrition.[35]

Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety, provides the basis for the assurance of a high level of protection of human health and consumers' interest in relation to food. Substances that are restricted include heavy metals, environmental chemical contaminants and mycotoxins. It is, however, unlikely that nanomaterials used in the production of food or food contact materials will be made using these toxic substances nor should they contain significant impurities of them.

Conclusions

Nanotechnology has the potential to transform the food industry by changing the way food is produced, processed, packaged, transported, and consumed. Applications in food packaging are very promising, because they can improve the safety and quality of food products; derived composites would reduce the requirement to use plastics as packaging materials, thus decreasing environmental pollution in addition to consuming less fossil fuel for their production.[31] New nanosensors are being tested to detect food pathogens. Basic array techniques with thousands of nanoparticles on a platform have been designed to fluoresce with different colors on contact with food pathogens. Furthermore, intelligent packaging with nanosensors is being considered that has the ability to react to the environment and perhaps interact with the food product with specific applications. However nanomaterials might have toxic effects in the body because of their increased surface area compared to bulk materials.[32] Possible safety concerns limits extensive use of nanoparticles in foods as additives in the near future. Although nanomaterials from food packaging would not ordinarily be ingested or inhaled, the potential exists for unforeseen risk, such as release of airborne nanoparticles that might aggravate lung function or inadvertent consumption due to leakage of packaging materials into foods. The US FDA requires that manufacturers demonstrate that food ingredients and food products are not harmful to health, but specific regulations about nanoparticles do not exist. Although there is a lack of regulation and knowledge of risk, still there are a number of food and nutrition products that claim to contain nanoscale additives, including iron in nutritional drink mixes, micelles that carry vitamins, minerals and phytochemicals in oil, and zinc oxide in breakfast cereals. Measurement of exposure to nanomaterials is not yet well developed nor characterized, and the development of the research to better understand the possible health consequences of nanoparticles, is needed. To achieve this aim, governmental agencies and researchers are working together to proactively evaluate the benefits and harms of nanotechnology.

References

1. Whitesides GM. The 'right' size in nanobiotechnology. Nat Biotechnol 2003;21:1161-5.
2. Teoh GZ, Klanrit P, Kasimatis M, Seifalian AM. Role of nanotechnology in development of artificial organs. Minerva Med 2015;106:17-33.
3. Prasad R, Bhattacharyya A, Nguyen QD. Nanotechnology in sustainable agriculture: recent developments, challenges, and perspectives. Front Microbiol 2017;8:1014.
4. Wong JKL, Mohseni R, Hamidieh AA, MacLaren RE, Habib N, Seifalian AM. Will Nanotechnology Bring New Hope for Gene Delivery? Trends Biotechnol 2017;35:434-51.
5. Nano [Homepage]. Available from: www.nano.org [cited 2018, Feb 15].
6. Malik S, Krasheninnikov AV, Marchesan S. Advances in nanocarbon composite materials. Beilstein J Nanotechnol 2018;9:20-1.
7. Thiruvengadam M, Rajakumar G, Chung IM. Nanotechnology: current uses and future applications in the food industry. 3 Biotech 2018;8:74.
8. Kim DY, Kadam A, Shinde S, Saratale RG, Patra J, Ghodake G. Recent developments in nanotechnology transforming the agricultural sector: a transition replete with opportunities. J Sci Food Agric 2018;98:849-64.
9. Boyes WK, Thornton BLM, Al-Abed SR, Andersen CP, Bouchard DC, Burgess RM, *et al.* A comprehensive framework for evaluating the environmental health and safety implications of engineered nanomaterials. Crit Rev Toxicol 2017;47:767-810.
10. Buzby JC. Nanotechnology for food applications. More questions than answers. J Consum Aff 2010;44:528-45.
11. Singh T, Shukla S, Kumar P, Wahla V, Bajpai VK. Application of nanotechnology in food science: perception and overview. Front Microbiol 2017;8:1501.
12. Sharma C, Dhiman R, Rokana N, Panwar H. Nanotechnology: an untapped resource for food packaging. Front Microbiol 2017;8:173.
13. Villegas C, Torres A, Rios M, Rojas A, Romero J, de Dicastillo CL, *et al.* Supercritical impregnation of cinnamaldehyde into polylactic acid as a route to develop antibacterial food packaging materials. Food Res Int 2017;99(Pt 1):650-9.

14. Kim TY, Song EH, Kang BH, Kim SJ, Lee YH, Ju BK. Hydrolyzed hexagonal boron nitride/polymer nanocomposites for transparent gas barrier film. Nanotechnology 2017;28:12LT01.
15. Müller K, Bugnicourt E, Latorre M, Jorda M, Echegoyen Sanz Y, Lagaron JM, *et al.* Review on the processing and properties of polymer nanocomposites and nanocoatings and their applications in the packaging, automotive and solar energy fields. Nanomaterials (Basel) 2017;7.
16. Pathakoti K, Manubolu M, Hwang HM. Nanostructures: current uses and future applications in food science. J Food Drug Anal 2017;25:245-53.
17. Bumbudsanpharoke N, Choi J, Ko S. Applications of Nanomaterials in Food Packaging. J Nanosci Nanotechnol 2015;15:6357-72.
18. Tamayo L, Azócar M, Kogan M, Riveros A, Páez M. Copper-polymer nanocomposites: An excellent and cost-effective biocide for use on antibacterial surfaces. Mater Sci Eng C Mater Biol Appl 2016;69:1391-409.
19. Jokar M, Pedersen GA, Loeschner K. Six open questions about the migration of engineered nano-objects from polymer-based food-contact materials: a review. Food Addit Contam Part A Chem Anal Control Expo Risk Assess 2017;34:434-50.
20. Reddy PV, Hernandez-Viezcas JA, Peralta-Videa JR, Gardea-Torresdey JL. Lessons learned: Are engineered nanomaterials toxic to terrestrial plants? Sci Total Environ 2016;568:470-9.
21. Jahan S, Yusoff IB, Alias YB, Bakar AFBA. Reviews of the toxicity behavior of five potential engineered nanomaterials (ENMs) into the aquatic ecosystem. Toxicol Rep 2017;4:211-20.
22. Wright MV, Matson CW, Baker LS, Castellon BT, Watkins PS, King RS. Titanium dioxide nanoparticle exposure reduces algal biomass and alters algal assemblage composition in wastewater effluent-dominated stream mesocosms. Sci Total Environ 2018;626:357-36.
23. Vithanage M, Seneviratne M, Ahmad M, Sarkar B, Ok YS. Contrasting effects of engineered carbon nanotubes on plants: a review. Environ Geochem Health 2017;39:1421-39.
24. Kookana RS, Boxall AB, Reeves PT, Ashauer R, Beulke S, Chaudhry Q, *et al.* Nanopesticides: guiding principles for regulatory evaluation of environmental risks. Agric Food Chem 2014;62:4227-40.
25. Final Nanotechnology White Paper. 2007. Office of the Science Advisor [Internet]. Available from: http://www.epa.gov/osa/nanotech.htm [cited 2014, Mar 11].
26. Li Z, Sheng C. Nanosensors for food safety. J Nanosci Nanotechnol 2014;14:905-12.
27. Agrawal GK, Timperio AM, Zolla L, Bansal V, Shukla R, Rakwal R. Biomarker discovery and applications for foods and beverages: proteomics to nanoproteomics. J Proteomics 2013;93:74-92.
28. Khater M, de la Escosura-Muñiz A, Merkoçi A. Biosensors for plant pathogen detection. Biosens Bioelectron 2017;93:72-86.
29. Ruttkay-Nedecky B, Krystofova O, Nejdl L, Adam V. Nanoparticles based on essential metals and their phytotoxicity. J Nanobiotechnology 2017;15:33.
30. Vazquez-Muñoz R, Borrego B, Juárez-Moreno K, García-García M, Mota Morales JD, Bogdanchikova N, *et al.* Toxicity of silver nanoparticles in biological systems: Does the complexity of biological systems matter? Toxicol Lett 2017;276:11-20.
31. Smith SS. Nanotechnology of emerging targeting systems. Minerva Biotecnol 2008;20:127-31.
32. Hamad AF, Han JH, Kim BC, Rather IA. The intertwine of nanotechnology with the food industry. Saudi J Biol Sci 2018;25:27-30
33. Tolve R, Galgano F, Caruso MC, Tchuenbou-Magaia FL, Condelli N, Favati F, *et al.* Encapsulation of health-promoting ingredients: applications in foodstuffs. Int J Food Sci Nutr 2016;67:888-918.
34. Bosnea LA, Moschakis T, Biliaderis CG. Microencapsulated cells of Lactobacillus paracasei subsp. paracasei in biopolymer complex coacervates and their function in a yogurt matrix. Food Funct 2017;8:554-62.
35. Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28.01.2002, Official Journal L 031, 01/02/2002 P. 0001-0024.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Manuscript accepted: February 14, 2018. - Manuscript received: February 7, 2018.