International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 10, Issue 7, 2018, pp.-5730-5733.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

RELEVANCE OF NANOTECHNOLOGY IN FOOD PROCESSING INDUSTRIES

UMACHANDRAN KRISHNAN[1], SAWICKA BARBARA[2], MOHAMMED ARIFULLAH[3], NASIR NOORI ABDUL-NABI[4] AND PASQUALONE ANTONELLA[5]

[1]Nelcast Ltd., 159 TTK Road, Alwarpet, Chennai, India
[2]Department of Plant Production Technology and Commodity Sciences, University of Life Sciences, 20-950, Lublin, Akademicka 15, Poland
[3]Faculty of Agro Based Industry, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia
[4]Vertebrate Department, Marine Science Center, University of Basrah, Basrah, Iraq
[5]Department of Soil, Plant, and Food Science (Di.S.S.P.A.), Food Science and Technology Unit, University of Bari 'Aldo Moro', Via Amendola, 165/A, 70126, Bari, Italy
*Corresponding Author: Email-umachandran_k@hotmail.com

Received: April 02, 2018; Revised: April 11, 2018; Accepted: April 12, 2018; Published: April 15, 2018

Abstract- Nanotechnology is one of the innovative technologies including the production and / or control of structures, devices, or materials in which at least one dimension is from 1 to 100 nanometers. Nanotechnology has found wide application in many areas of life and economy, *inter alia* in: health care, pharmacy, agriculture, food processing, transport, energy, and information technology. This technology will revolutionize the agricultural and food industry through innovative tools for efficient processing, storage and packaging systems throughout the whole food supply chain. This paper covers the nanotechnology applications in food processing industries aimed at improving taste, texture, and consistency, or at developing polymers to improve food packaging, distribution, and shelf-life. Nano-sensors to detect food contaminants and 'smart' food development are also reviewed. Attention is also paid to the risk of using nanomaterials for human health and the environment.

Keywords- Nanotechnology, Nano-Food, Nanostructures, Biosensors.

Citation: Umachandran Krishnan, *et al*., (2018) Relevance of Nanotechnology in Food Processing Industries. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 7, pp.-5730-5733.

Introduction

Nanotechnology is an applied science involving the engineering of very small systems and structures. According to the EU definition, a "nanomaterial" is composed of particles whose size is in the range 1-100 nm for at least 50% of total. This size range is imposed by several organizations, including the International Organization for Standardization (ISO) [1]. Nanostructures are the smallest solid possible to be made and are intermediate between isolated atoms or molecules and macroscopic matter. At the 1-100 nm size scale the matter offers physical and chemical properties different from the macroscopic level. Therefore, nanotechnology works with materials in nanometric scale to confer them new properties. The techniques used to reduce particle size so as to obtain nanostructures are, among others, low flow injection, precipitation by antisolvents, and evaporation. Hence, nanotechnology is a set of technologies that allows the manipulation, study or exploitation of very small structures and systems. The rapid development of nanotechnology is encouraged by an evolving scenario for unearthing, classifying, and releasing nanoscale materials and knowledge in a multidisciplinary frame. Nanoscale devices have been applied to biotechnology, information technologies, and cognitive sciences. In addition, nanotechnology displays a great potential in the agricultural and food industry, where it can play a key role in the controlled release of herbicides and fertilizers, as well as in food processing and packaging, and for raising the overall level of food safety. Nanotechnology allows innovating the formulation of agrochemicals (fertilizers, pesticides, veterinary medicines), and allow developing nanomaterials able to enhance pest management and crop protection due to improved effectiveness, better bio accessibility of active ingredients, and controlled release [2]. Nanotechnology in food industries is expected to bring innovation in three forms: i) by the set up of innovative process enablers, such as nanoencapsulated materials and biopolymers; ii) by means of new packaging polymers and composites; iii) by the development of nanosensors and carriers useful to check food quality and safety, and monitor shelf-life. The relevance of nanotechnology in food processing industries is schematized in [Fig-1]. Therefore, innovations in nano areas have a significant impact on both agriculture and food industries [3], which use this innovative technology to strategize food product with greater value-added, market precision, and affordable costs.

Opportunities on the way

Bringing nanotechnology specific science-to-market perspectives will lead to nano enabled developments, necessarily the best in science or technology to the challenging problems of agricultural, environmental and ethical or social impact on economy. The application of nanotechnologies in agriculture and, food industry and consumers applications can help to attain the UN millennium goal by impacting food safety and food security [4]. Nano-particles have a comparably greater surface area than their original equivalents, therefore show totally different tendency to agglomerate, as well as different catalytic surface, and activity. The nanoscale materials have a wide range of applications in food and beverage sector, allowing cost-effective development of innovative functional foods, active packaging, and nonosensors for detecting microbial contaminants or allergens [5]. Nanotechnology potential applications in food industry can modify color, flavor, or nutrients to suit individual customer favor or health requirements and can inform the consumers about the safety status of food inside packaging. Flavors can be adapted by sorting certain atoms or molecules based on size, and active packaging can be used to detect spoilage by color change.

Applications of nanotechnology in agriculture and food industry

Nanotechnology leads potential applications in the whole food chain, from the field

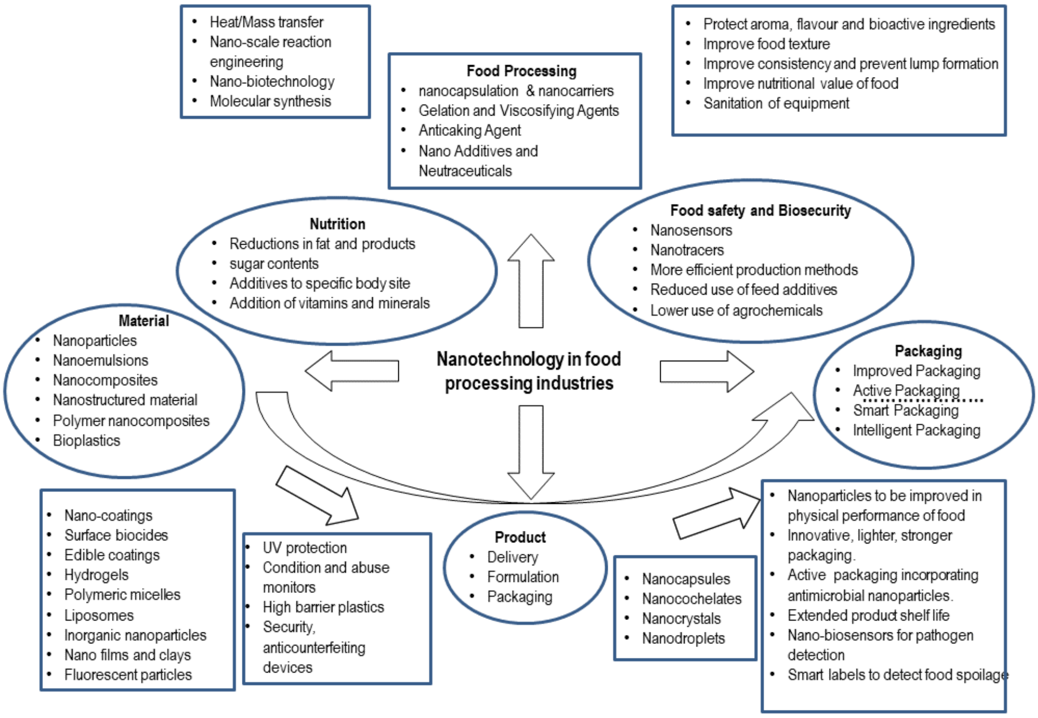

Fig-1 Relevance of nanotechnology in food processing industries

to the table, equally minimizing health and environmental risks. Agricultural nanotechnology, in particular, helps solving farmer's problems, as summarized in [Table-1]. The need for higher agricultural production has increased cultivation areas and consumption of water. Nanotechnologies could help water and soil cleaning and remediation. In addition, nano-control systems could help monitoring crops to determine the right harvest moment and could control the release of herbicides and fertilizers. Combined with biotechnology, nanotechnology has a great potential in crop improvement [1]. In particular, nanotechnology can be exploited to develop nanostructures which can act as new gene vectors, instead of conventional viral vectors, or as structures capable to prompt and regulate gene expression, useful in molecular-based breeding of crops [6].

Nanotechnology applied to the food industry sector allows releasing engineered food nanomaterials such as: i) food with an innovative and deliberately modified primary molecular structure; ii) food comprising or derived from microorganisms, fungi and algae; iii) food developed from plants through conventional proliferating process; iv) food from cellular tissue cultures; food consisting of, or isolated from animals, including insects, obtained by common reproduction practices with a proven ability for consumption [1]. Nanotechnology allows dissolving essences that are not normally soluble such as vitamins, minerals, antioxidants, phytochemicals, and nourishing oils. The development of nanostructures such as nanoemulsions implies the modification of food unit operations to introduce homogenization and emulsification steps carried out at high-pressure, ultrasound treatments, dry-ball and dry-jet milling [6]. Nano-additives such as nanocellulose can be used in food industry as stabilizing agent, functional food ingredient, and emulsifier [7] and can be exploited in food packaging, including active packaging set up [8].

Food safety is nowadays threatened by several contaminants such as bacteria and their toxins, pesticide residues, heavy metals, and baking-derived toxic substances such as acrylamide and polycyclic aromatic hydrocarbons (PAH). Sensitive and fast analytical techniques are always needed. A self-generated surface-sampling method called liquid extraction surface analysis (LESA), together with infusion nano-electrospray high-resolution mass spectrometry and in addition to tandem mass spectrometry (MS/MS), can be used for the examination of pesticides remains in fruits and vegetables. Nano-analytical electron microscopy techniques, instead, have been proposed in medicine, but other fields of application cannot be excluded.

"Smart food", "smart packaging" and nanosensors

Nanotechnology proved to be a useful tool throughout the whole food chain: from crop cultivation, to food processing and packaging [9]. The potentialities of applying nanotechnology in food industries are summarized in [Table-2]. Kraft and Nestlé and others are already developing "intelligent" food that will interact with consumers and change color, taste or nutrients at their request. For example, Kraft developed a beverage containing numerous flavors as invisible nanocapsules [6]. An ordinary home microwave oven can be used to start the process of activating color and taste or modifying the consistency of food depending on individual preferences. "Intelligent" food can also sense whether a person is allergic to any of the ingredients and block it, while "smart" packaging can release specific nutrients for consumers with particular dietary needs, e.g. calcium in the case of people suffering from osteoporosis [9]. Nanopackaging has been one of the earliest commercial applications in the food industry. Numerous nanopackaging types are already marketed, and there is great potential for further increase, also to extend the shelf life of food. Carbon nanotubes are a recent material which can be effectively exploited in food packaging applications for extending shelf-life, due to its ability in eliminating carbon dioxide from packaging headspace [4,9]. In addition, Mars Inc. patented an edible nanopackaging, not visible but able to prevent the exchange of gases and moisture between food and environment [9]. Also, containers with coatings of nanosilver particles have been developed, able to inhibit the microbial growth. The nanosilver-based packaging can preserve foods from spoilage and, if equipped with a nanotechnology sensor, can also detect food degradation [9].

Nanosensors are similar to ordinary sensors, but at the nanoscale. "Intelligent" packaging with nanosensors and eventually antimicrobial activators will be able to monitor food degradation during storage and to extend its shelf life [Table-2]. These advanced nanosensors are based on engineered bacteria able to respond to specific physicochemical or biological targets and then to transfer that response into an output signal [10,11]. Nanotechnology can be applied also in the field of food chain traceability.

The nanosensors in food packaging can act as electronic barcodes, i.e. nano-Radio Frequency Identification (RFID) tags. The signal emitted by the tags will allow to track food from the field to the factory, and then to the supermarket and beyond [9-,11,12]. Nanotechnology will modify the food chain operations and influence the entrepreneur's choices. With the swift evolution of discovery, characterization, and application of nanoscale materials in the region of farming, food safety and biosecurity, nanotechnology provides sensors to detect food spoilage, therefore reducing unnecessary waste, saving consumer's money, and relieving pressures on landfill and food production.

Table-1 *Potentialities of applying nanotechnology in agriculture.*

Area	Research focus	Tool
Crop cultivation	Agrochemicals	Nanocapsules, nanoemulsions, nanoparticles and viral capsids for efficient application of active ingredients for controlling plant diseases and pest
	Fertilizers	Nanocapsules, nanoparticles and viral capsids for effective nutrients and growth hormones absorption by plants; nanoemulsions; triggered release nanoencapsulated devices
Soil improvement	Water loss decrease	Zeolites and nanoclays for enhancing the retaining of water and/or liquid agrochemicals by the soil
Water quality	Water cleaning	Nanoclays able to bind toxic substances to be removed from the environment
	Water purification and soil cleaning	Filters with nanopores Nanoparticles
Diagnostics	Nanosensors	Diagnostic nanodevices such as carbon nanotubes, nanofibers, and fullerenes, acting as nanosensors for monitoring plant growth and detecting plant diseases
Plant breeding	Nanovectors	Nanovectors to carry genetic material and regulate gene expression
Plant-derived nanomaterials	Nanomaterials	Nanomaterials obtained from engineered plants or bacteria or derived from agricultural wastes

Elaboration from: [6].

Social and economic impact of food nanotechnology

In a future scenario, food could be created by shaping atoms and molecules by means of nanotechnology and then packaged in 'intelligent', safe containers capable of detecting spoilage or harmful contaminants. The products of the future will strengthen and change their colors, flavors or nutrient content, so as to satisfy the tastes of each consumer and the needs resulting from personal health state. In agriculture, nanotechnology promises to reduce the use of pesticides, improve the efficiency of animal and plant breeding and the creation of new bio-industrial products [9]. The food and agricultural industry has already invested billions of dollars in nanotechnology research, however, in the absence of the obligation to label such products worldwide, it is currently impossible to determine how many commercial food products contain nano-ingredients [4]. The Helmut Kaiser Consulting Group, an analyst with pro-tech attitude, reports that there are currently approximately 300 nano-food products around the world.

Table-2 *Potentialities of applying nanotechnology in food industries.*

Field of application	Tool
Food processing	Nanocapsules and nanoemulsions to improve bioavailability of nutrients
	Nanoencapsulated flavor enhancers
	Nanotubes and nanoparticles as thickening agents
	Nanoparticles able to bind and remove food contaminants
Food packaging	Smart packagings and nanosensors to monitor temperature and moisture and / or for food traceability
	Fluorescent antibody-linked nanoparticles to detect food contaminants
	Nanofilms as barrier materials to prevent food oxidation
	Electrochemical nanosensors to detect ethylene
	Silver, magnesium, and zinc nanoparticle coatings with antimicrobial activity
	Films containing silicate nanoparticles, featuring strength and resistance to heat
Food supplements	Nanocapsulated phytosterols to lower cholesterol dietary intake
	Nanocellulose composites as drug carrier
	Nanoencapsulation of nutraceuticals for better absorption, better stability, or targeted delivery
	Coiled nanoparticles to efficiently provide for nutrients
	Nano droplets of vitamins obtained by spraying for enhanced absorption

Elaboration from: [9, 14-18].

The global nano-food market in 2005 accounted for 5.3 billion dollars, and in 2010 its value increased to 20.4 billion dollars [13]. It is estimated that in 2020 nanotechnology will be used in at least 40% of the food industry [9,13]. In research on nanotechnology in food, four basic directions are distinguished:

- nanomodification of seeds and fertilizers or pesticides;
- strengthening ("fortification") and food modification;
- interactive, "smart" food [12];
- "Smart" food packaging and its tracking [12].

However, despite the many advantages, it is necessary to carry out a very thorough risk assessment for nano-waste [19].

Threats related to food nanotechnology

Innovations in nano-related fields have several helpful applications in agriculture and food industry. Although food nanotechnology has enormous advantages and potential, public perceptions are generally negative. The health implications of food processing techniques that produce nanoparticles are worth attention. Risk evaluation and consumer perception are significant topics in nanotechnology to be considered in analogous with the growth and application. Essential to risk evaluation of nanotechnologies are its applications in food products necessitating progressive research in the fields of classifying nanoparticles, dosage levels, impact and effects, regulation, consumer acquaintance. If novel productive processes lead to alter food composition, then detailed studies have to be carried out on the nutritional value, metabolism, and possible contaminants, including allergens. The potential for novel nano-ingredients to pose health risks has to be deeply studied.

There have been many debates on food safety that have been produced directly or indirectly from a nanomaterial. Recently, there have been warnings from scientists about possible health risks related to nanomaterials because, due to their size, they can enter the cells and accumulate, potentially causing various diseases. It has been shown that carbon nanotubes can damage the lungs, because their structure and size make it impossible to remove them from the body. It is assumed that the toxic effects of fullerenes result from the ability to capture electrons from neighboring particles and the formation of radicals that are suspected of carcinogenic traits [17]. There are also reports on the toxic effects of nanoparticles, such as titanium, cobalt, iron, tungsten and even silver [9]. Nanostructures are more reactive and mobile than larger molecules, therefore their toxicity to humans and the environment could be higher.

Initial scientific studies have shown that many types of nanoparticles can lead to increased oxidative stress, which leads to the formation of free radicals capable of inducing cancer, DNA mutation and even cell death. Fullerene − carbon nanoparticles − causes damage to the brain of the large grouper, which was adopted by the regulatory agencies as a benchmark for determining the degree of environmental poisoning. Great Britain also warns of the serious threat of nanotoxicity and recommends that nanoparticle components would have to be subjected to their full extent of innocuity assessment by the appropriate scientific institution before being approved for use in products. Despite this warning, there are still no rules governing the use of nanomaterials in consumer products that would determine their harmlessness to users, laborers or the environment to which waste nanoproducts are discharged. Many threats posed by the opponents of nanotechnology that may appear in the future mention the danger of cancer as possible result of incorrectly placed "nanorobots" in the human body and environment, or their malfunction, which may lead to self-replication or changing the tasks fulfilled.

In addition, the so-called "Green Goo scenario" warns of the risk of losing control over nanorobots with subsequent disastrous effects [9]. To prevent such risks, research should be conducted. The application of nanomaterials in food packaging for traceability purposes will also create new problems related to the protection of privacy. Despite the release of nanotechnology foods and agricultural products to supermarkets and the environment, governments around the world have done nothing to create any rules that limit the risks of nanotechnology [1,5] studied crystal imperfections, such as lattice strains, degree of lattice distortion, internal stress and dislocation density of $Bi_xZn_{1-x}O$ nanoparticles. Morphological assessment showed that increasing the Bi-content improved the crystallization process, increased the crystalline agglomerations and minimized the crystal imperfections.

Conclusion

As reviewed, nanotechnology in the scenario of agriculture and food processing industry can lead into exhaustive applicability in developing nano-formulations of agrochemicals, and allowing food changing color, flavor or nutritional characteristics to meet the consumer preference and dietary needs. Nano-packaging allows prolonging shelf life and retaining freshness of food and, with the additions of nanosensors, can effectively trace items along the food chain [12,18]. Therefore, the European Commission considers nanotechnology as one of the key technologies in agriculture and food sector, able to face climate change and improve food security at global level [6]. The nanomaterials offer different physico-chemical properties compared to the macroscopic counterpart. The nanostructures devices guide the matter at the atom level in biotechnology, life, physical, and chemical sciences connecting particles of different materials to provide advancements in several fields, from medicine to food production. The real challenge in using nanotechnologies is the reliability of manufacture working on nanoscale devices. On mastery over this peculiar technology, it can lead to valuable opportunities in an array of fields. Nanotechnologies in process, polymers, composites and sensors aim to improve delivery of food processing units while creating significant health benefits and improving taste, texture, consistency, and shelf-life. The latter takes advantage of a reduction in microbial growth by corrective inclusion in nanosystems of carriers to counteract the contaminants. However, the uncertainties regarding the potential health risks of nano-materials are a major concern. There are also many misconceptions about nanotechnologies, hence transparency and research deepening are the keys to the development of these powerful tools. Research output from risk assessment studies would allow regulatory agencies to identify potential critical points in the use of nanotechnologies and manufactured nanomaterials in food.

Application of review: This paper is a precursor to all the nanotechnology researches in process, polymers, composites and sensors projecting to progress healthy delivery in food processing industry for handling uncertainties and health related risks.

Review Category: Nanotechnology applications

Acknowledgement / Funding: Author thankful to Nelcast Ltd., 159 TTK Road, Alwarpet, Chennai, India

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Laaninen T. (2015) *European Parliamentary Research Service*, PE 564.383, pp. 8.

[2] Aschberger K., Gottardo S., Amenta V., Arena M., Botelho Moniz F., Bouwmeester H., Brandhoff P., Mech A., Pesudo Q.L., Rauscher H., Schoonjans R., Vettori V.M. and Peters R. (2015) *Journal of Physics*: *Conference Series*, pp. 7.

[3] Bautista S. and Jiménez-Aparicio A. (2016) *Chitosan in the Preservation of Agricultural Commodities*, ISBN: 978-0-12-802735-6, pp. 366

[4] Sabourin V. and Ayande A. (2015) *Journal of Technology Management & Innovation,* 10(1), Santiago 2015, ISSN 0718-2724,

[5] Hassanien A.S., Akl A.A. and Sáaedi A.H. (2018) *Crystals Engineering Communications*, DOI: 10.1039/c7ce02173a

[6] Parisi C., Vigani M. and Rodríguez-Cerezo E. (2015) *Nanotoday Direct,* 10(2), 124–127.

[7] Serpa A., Velásquez-Cock J., Gañán P., Castro C., Vélez L. and Zuluaga R. (2016) *Food Hydrocolloids*, 57, 178-186.

[8] El-Wakil N.A., Hassan E.A., Abou-Zeid R.E. and Dufresne A. (2015) *Carbohydrate Polymers*, 124, 337-346.

[9] Ijabadeniyi O.A. (2017) Quality and Safety of Nanofood. [in:] *Nanotechnology in Agriculture and Food Science*. Ed. Axelos M.A., Van de Voorde M.H. on-line, DOI: 10.1002/9783527697724.ch17

[10] Garcia-Martinez J. (2016) The Internet of Things Goes Nano, https://www.scientificamerican.com/article/the-internet-of-things-goes-nano/.

[11] Omanović-Mikličanina E. and Maksimović M. (2016) *Bulletin of the Chemists and Technologists of Bosnia and Herzegovina,* 47, 59-70.

[12] Hamilton G. (2017) *Horizon Scan, 2*, ISBN 978-1-74254-956-9, 1-37. http://www.agrifutures.com.au/wp-content/uploads/publications/17-033.pdf

[13] Kaiser H. (2018) Food processing, Agriculture, Packaging and Consumption. State of Science, Technologies, Markets, Applications and Developments to 2015 and 2040. *Nano Food 2040* http://www.hkc22.com/nanofood2040.html

[14] Karcher S.C., Harper B.J., Harper S.L., Hendren C.O. and Wiesner A. (2016) *Environmental Science: Nano,* 3, 1280-1292.

[15] Ozmen M., Güngördü A., Erdemoglu S., Ozmen N. and Asilturk M. (2015) *Toxicology of Water,* 165, 144-153.

[16] Rico C. (2015) *Nanomaterial Implications for Agricultural Productivity and Food Safety,* http://www.azonano.com/article.aspx, (20/12/2016)

[17] Golmohammadi H., Morales-Narváez E., Naghdi T. and Merkoçi A. (2017) *Chemistry of Material,* 29(13), 5426–5446.

[18] Canli E.G. and Canli M. (2016) *Journal of the International Society of Antioxidants in Nutrition & Health,* 1512-1523.

[19] De Moraes Carvalho D., Takeuchi K.P., Geraldine R.M., de Moura C., Torres L.M.C. (2015) Production, solubility and antioxidant activity of curcumin nanosuspension, *Food Science and Technology* (Campinas) 35(1), http://www.scielo.br/scielo.php.