

NANOTECHNOLOGIES IN FOOD AND MEAT PROCESSING

Lech Ozimek¹, Edward Pospiech², Suresh Narine³

¹University of Alberta in Edmonton, Canada

²Poznań University of Life Sciences, Poland

³Trent University in Peterborough, Canada

Abstract. This paper highlights the evolution of nanoscience and nanotechnologies from the global perspective and their potential application in food systems including meat processing. Nanotechnology has its roots in a talk delivered in 1959 by physicist Richard Feynman to the American Physical Society. Nanoscience refers to components properties at nanoscale and nanotechnology refers to process or processes used in the manufacture and/or biofabrication of new materials measured at nanoscale. Nanotechnology offers a wide range of opportunities for the development of innovative products and applications in food system. Functional foods, nutraceuticals, bioactives, farmafoods, etc. are very recent example of it. Nanotechnology and nanomaterials are a natural part of food processing and conventional foods, because the characteristic properties of many foods rely on nanometer sized components. Some of the areas where nanotechnologies are set to make a difference in meat processing in near future relate to intelligent packaging of meat and meat products, meat derived bioactive peptides, pro- and pre-biotics inclusion in processed meat products, fat based nanoemulsions for antioxidant delivery, nanosensors and nanotracers for meat biosecurity tracing and nanostructured meat products with defined functions. New horizons for nanotechnology in meat science may be achieved by further research on nanoscale structures and methods to control interactions between single molecules. However, it shall be mentioned that nanotechnologies and nanomaterials are calling for their regulations and safety assessment as some of the materials are new and their safety never tested before.

Key words: nanotechnology, nanomaterials, nanofoods, innovative products, bioactive molecules, regulations and safety of nanoproducts

INTRODUCTION

Nanotechnology is the manufacture and use of materials and structures at the nanometre scale (a nanometre is one millionth of a millimetre). It offers a wide range of opportunities for the development of innovative products and applications in food system. Nanotechnology and nanomaterials are a natural part of food processing and conventional foods, because the characteristic properties of many foods rely on nanometer sized components, for example, nanoemulsions and foams. Recent technological developments lead the way for the manufacture of nanoparticles to be added to food. These could be finely divided forms of existing ingredients, or completely novel chemical structures. While many definitions for nanotechnology exist, the National Nanotechnology Initiative calls it “nanotechnology” only, if it involves all of the following:

- 1) research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1-100 nanometer range
- 2) creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size
- 3) ability to control or manipulate on the atomic scale.

After industrial revolution of the last two centuries the nanotechnology initiated the second technical revolution as a function of growth innovations. We are only at the beginning of nanotechnology growth. Nanotechnology applications in the food sector are on the increase worldwide and are expected to grow rapidly in the future. The types of material produced can be at the nanoscale in one dimension (very thin coatings), two dimensions (nanowires) or three dimensions (nanoparticles, such as a very fine powder preparations). Nanotechnologies are not new and scientists have been making polymers based on nanoscale subunits for many years. Due to new, previously unknown, properties attributed to engineered nanoparticles (NP) many new consumer products containing these NPs have been launched to the market recently. Application of NPs in electronics, medicine, textiles, defence, food, agriculture, cosmetics, and other areas are already a reality and applications are beginning to impact the food processing industries [Chen et al. 2006]. The potential benefits for consumers and producers of these new products are widely emphasized. In food and agricultural systems nanotechnologies cover many aspects, such as food security, packaging materials, disease treatment, delivery systems, bioavailability, new tools for molecular and cellular biology and new materials for pathogen detection [Maynard et al. 2006, Jasińska et al. 2010]. Nanoparticles have tremendous potential for application in agro-food production i.e. processing of pesticides, fertilizers, food additives, cosmetics, feed (e.g. vitamins), packaging and textiles.

Nanotechnologies are key technologies of the 21st century, and huge research efforts are made in this field. New applications may become available in near future. Because applications with structural features on the nanoscale level have physical, chemical, and biological properties that are substantially different from their macroscopic counterparts, nanotechnology can be beneficial on various levels. Research in biology, chemistry, engineering, and physics drives the development and exploration of the nanotechnology field. Consequently, certain industries such as microelectronics, aerospace, and pharmaceuticals have already begun manufacturing commercial products of nanoscale size. Even though the food industry is just beginning to explore its applications, nanotechnology exhibits great potential.

Food undergoes a variety of postharvest and processing-induced modifications that affect its biological and biochemical makeup, so nanotechnology developments in the fields of biology and biochemistry could also influence the food industry. Systems with structural features in the nanometer length range could affect aspects from food safety to molecular synthesis.

Nanotechnology focuses on the characterization, fabrication, and manipulation of biological and nonbiological structures smaller than 100 nm. Structures on this scale have been shown to have unique and novel functional properties. Interest and activities in this research area have greatly increased over the past few years. The use of the term “nano” does allow to highlight the fact that processes or material structures are designed and optimized to use specific properties and behaviours at lengths of 10^{-7} to 10^{-9} m.

NANOSTRUCTURES/NANOMATERIALS

Nanostructures are materials that, in at least one dimension, measure approximately 1-100 nm. Nanostructures or nanomaterials exhibit properties different from their macroscale counterparts (their “big brothers”) such as mechanical strength (how hard they are to break), electrical conductivity (how fast electrons flow through them), thermal conductivity (how fast heat flows through them), chemical reactivity (how well/fast they react with other chemicals), transparency (how well you can see through them) and magnetism (whether or not they are magnetic). Discoveries in nanotechnology are beginning to impact the food industry and associated industries. This affects important aspects from food safety to the molecular synthesis of new food products and ingredients [Chen et al. 2006]. Range of sizes of nanomaterials in the food sector and their relative position on nanoscale/microscopic scale are listed below.

Structures	Diameter or length, nm
DNA	12
Glucose	21-75
Liposome	30-10 000
LDH	40-300
Amylopectin	44-200
Casein micelle	60-300
Zein	200
Nanosensors	<1000

Nanotechnology allows to measure, control, and manipulate matter at the nanoscale level to change those properties and functions in a beneficial way. Developments in nanotechnology are driven by fundamental and applied research in physics, chemistry, biology, engineering, and materials science. Nanotechnology provides the tools to measure and understand biosystems in science and technology platform. The potential benefits of nanofoods are astonishing. Advocates of the technology promise improved food processing, packaging and safety; enhanced flavor and nutrition; ‘functional foods’ where everyday foods carry medicines and supplements, and increased production and cost-effectiveness. In a world where thousands of people starve each

day, increased production alone is enough to warrant worldwide support. For the past few years, the food industry has been investing millions of dollars in nanotechnology research and development. Some of the world's largest food manufacturers, including Nestle, Altria, H.J. Heinz and Unilever, are blazing the trail, while hundreds of smaller companies follow their lead. Yet, despite the potential benefits, compared with other nanotechnology arenas, nanofoods don't get a lot of publicity. Applications of nanotechnology within the food industry are beginning to impact the important aspects of food and associated industries from food safety to the molecular synthesis of new food products and ingredients [Chen et al. 2006]. The fact that systems with structural features on the nanoscale have physical, chemical, and biological properties substantially different from their macroscopic counterparts is changing the understanding of biological and physical phenomena in food systems.

Foods are complex biological systems that are governed by many of the same basic mechanisms and principles as in biology and biochemistry. Therefore, the discoveries made in nanotechnology will also impact the food industry. Nanotechnology allows to measure, control, and manipulate matter at the nanoscale level to change those properties and functions. Food is "nanofood" when nanoparticles, nanotechnology techniques or tools are used during cultivation, production, processing, or packaging of the food. It does not mean atomically modified food or food produced by nanomachines.

In the forefront of nanofood development is Kraft Foods, which took the industry's lead when it established the Nanotek Consortium, a collaboration of 15 universities and national research labs, in 2000. Kraft's focus is on "interactive" foods and beverages. These products will be customized to fit the tastes and needs of consumers at an individual level. Possible products include drinks that change colors and flavors to foods that can recognize and adjust to a consumer's allergies or nutritional needs. Other large companies, such as Nestlé and Unilever, are exploring improved emulsifiers that will make food texture more uniform. In Australia for instance, nanocapsules are used to add omega-3 fatty acids to one of the country's most popular brands of white bread. According to the manufacturer, nanocapsules of tuna fish oil added to Tip Top Bread provide valuable nutrients, while the encapsulation prevents the bread from tasting fishy. These huge western companies are responsible for the bulk of the food industry's research and development, however the nanofood industry is truly a global phenomenon. Summarizing, it can be said that the possible nanoscale size effect comprise:

- realization of miniaturized devices and systems while providing more functionality
- attainment of high surface area to volume ratio
- manifestation of novel phenomena and properties, including changes in physical (e.g. melting point), chemical (e.g. reactivity), electrical (e.g. conductivity), mechanical (e.g. strength) and optical properties (e.g. light emission).

NANOTECHNOLOGY – SCIENCE AND TECHNOLOGY

Nanotechnology has the potential to impact many aspects of food and agricultural systems. Food security, disease treatment delivery methods, new tools for molecular and cellular biology, new materials for pathogen detection, and protection of the environment are examples of the important links of nanotechnology to the science and engi-

neering of agriculture and food systems. Examples of nanotechnology as a tool for achieving further advancements in the food industry are as follows:

- increased security of manufacturing, processing, and shipping of food products through sensors for pathogen and contaminant detection
- devices to maintain historical environmental records of a particular product and tracking of individual shipments
- systems that provide integration of sensing, localization, reporting, and remote control of food products (smart/intelligent systems) and that can increase efficacy and security of food processing and transportation
- encapsulation and delivery systems that carry, protect, and deliver functional food ingredients to their specific site of action.

Nanotechnologies and nanoparticles will affect food chain from primary production to consumer. Nanomaterials and nanostructures will provide specific function in targeted applications and some examples are listed below.

Type of nanoparticles	Application	Function
Metal nanoparticles (Silver, ZnO)	Food additive/supplement	Enhanced gastrointestinal uptake of metal
	Packaging materials/storage	Increase barrier properties
	Food preparation devices	Clean surface
	Refrigerators, storage containers	Anti-bacterial coating
Sprays	Water purification/soil cleaning	Removal/catalysation/oxidation of contaminants
	Refrigerators, storage containers	Anti-bacterial coating
Complex nanostructures	Nanosensors in packaging	Detection of food deterioration
	Hand-held devices	Monitoring of contaminants
Incorporated active nanoparticles	Storage conditions evaluation	Oxygen scavenging, prevention of growth of pathogens
	Migration out of packaging materials	Removal pathogens
Filters with nano-pores	Water purification	Removal pathogens
Nano-sized nutrients/foods	Delivery systems	Claimed enhanced uptake
	(nano-encapsulates)	Protecting and (targeted) delivery of content

Strategies to apply nanoscience to the food industry are quite different from these more traditional applications of nanotechnology. Food processing is a multi-technological manufacturing industry involving a wide variety of raw materials, high biosafety requirements, and well-regulated technological processes. Four major areas in food production may benefit from nanotechnology:

- development of new functional materials
- microscale and nanoscale processing
- product development
- methods and instrumentation design for improved food safety and biosecurity.

Application matrix of nanotechnology in food science and technology is schematically shown below (Fig. 1).

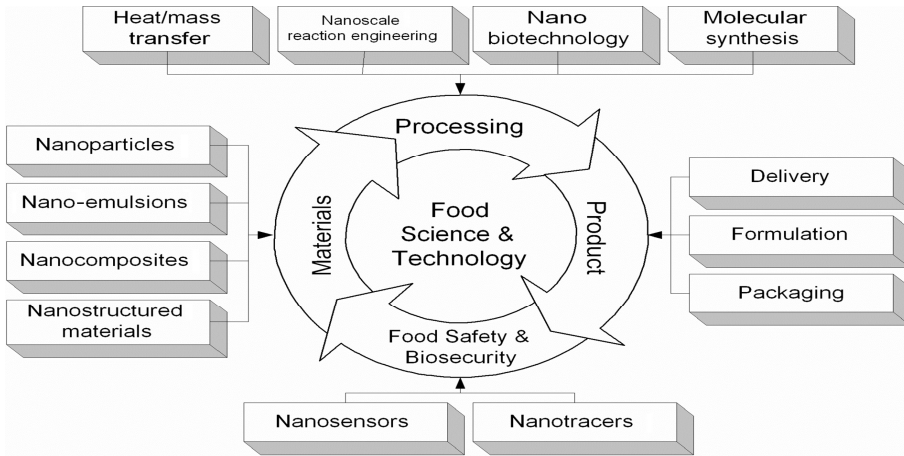


Fig. 1. Application matrix of nanotechnology in food science and technology

It may be stated that there are a large number of potential applications of nanotechnology within the food industry. Applications in food packaging are considered highly promising because they can improve the safety and quality of food products. This includes intelligent packaging, which is reactive to the environment and active packaging, which is able to interact with the food product. The estimated world market for nanofoods is rapidly growing and is estimated at \$ 20 billion in 2010 and 1 trillion by 2015 for the entire nanotechnology production.

NANOTECHNOLOGY IN DELIVERY OF NUTRACEUTICALS/FUNCTIONAL INGREDIENTS

The nano-sized self-assembled structured liquids (NSSL) technology allows for encapsulation of nutraceuticals, cosmeceuticals, and essential oils and drugs in food, pharmaceuticals, and cosmetics. Another advantage to the NSSL technology is that it allows the addition of insoluble compounds into food and cosmetics. One of the first products developed with this technology – a healthier version of canola oil – is already available to consumers in Israel.

NANODISPERSIONS AND NANOCAPSULES

The fundamental components of foods such as vitamins, antimicrobials, antioxidants, and preservatives come in various molecular and physical forms. They are rarely used in pure form, they are usually part of a delivery system. A delivery system has numerous functions, only one of which is to transport a functional ingredient to its desired site. Besides being compatible with food product attributes such as taste, texture, and shelf life, other functions of a delivery system include protecting an ingredient from

chemical or biological degradation, such as oxidation, and controlling the functional ingredient's rate of release under specific environmental conditions. Because they can effectively perform all these tasks, nanodispersions and nanocapsules are ideal mechanisms for delivery of functional ingredients. These types of nanostructures include: association colloids, nanoemulsions and biopolymeric nanoparticles. A delivery system must perform a number of different roles:

- it serves as a vehicle for carrying the functional ingredient to the desired site of action
- it may have to protect the functional ingredient from chemical or biological degradation (for example, oxidation) during processing, storage, and utilization; this maintains the functional ingredient in its active state
- it may have to be capable of controlling the release of the functional ingredient, such as the release rate or the specific environmental conditions that trigger release (for example, pH, ionic strength, or temperature)
- the delivery system has to be compatible with the other components in the system, as well as being compatible with the physicochemical and qualitative attributes (that is, appearance, texture, taste, and shelf-life) of the final product.

The characteristics of the delivery system are one of the most important factors influencing the efficacy of functional ingredients in many industrial products. A wide variety of delivery systems has been developed to encapsulate functional ingredients, including simple solutions, association colloids, emulsions, biopolymer matrices, and so on. Each type of delivery system has its own specific advantages and disadvantages for encapsulation, protection, and delivery of functional ingredients, as well as cost, regulatory status, ease of use, biodegradability, and biocompatibility.

ASSOCIATION COLLOIDS

A colloid is a stable system of a substance containing small particles dispersed throughout. An association colloid is a colloid whose particles are made up of even smaller molecules. Used for many years to deliver polar, nonpolar, and amphiphilic functional ingredients [Golding and Sein 2004, Garti and Benichou 2004, Garti et al. 2005, Bilska et al. 2009]. Association colloids range in size from 5 nm to 100 nm and are usually transparent solutions. Surfactant micelles, vesicles, bilayers, reverse micelles, and liquid crystals are all examples of association colloids. The major disadvantages to association colloids are that they may compromise the flavor of the ingredients and can spontaneously dissociate if diluted. The major advantages of association colloid systems are that they form spontaneously, are thermodynamically favorable, and are typically transparent solutions. The formation of association colloids is concentration-driven. Diluting the solutions containing the colloids can lead to their spontaneous dissociation. It is worth to mention that a large quantity of surfactant (and in many cases, co-surfactant) is required to form them, which may lead to problems with flavor, cost, or legality.

NANO-EMULSIONS

The use of high-pressure valve homogenizers or microfluidizers often causes emulsions with droplet diameters of less than 100 to 500 nm. In modern literature such emulsions are often referred to as “nano-emulsions”. They have been produced and studied for many years, so a large body of literature dealing with their preparation, characterization, and utilization exists [McClements 2004]. Functional food components can be incorporated within the droplets, the interfacial region, or the continuous phase [Jasińska et al. 2010]. Encapsulating functional components within the droplets often enables a slowdown of chemical degradation processes by engineering the properties of the interfacial layer surrounding them [McClements and Decker 2000].

NANOSTRUCTURED MULTIPLE EMULSIONS

The use of multiple emulsions can create delivery systems with novel encapsulation and delivery properties. The most common examples of this are oil-in-water-in-oil (O/W/O) and water-in-oil-in-water (W/O/W) emulsions [Garti and Benichou 2001, 2004]. Functional food components could be encapsulated within the inner water phase, the oil phase, or the outer water phase, thereby making it possible to develop a single delivery system that contains multiple functional components [Flanagan and Singh 2006].

BIOPOLYMERIC NANOPARTICLES

Food-grade biopolymers such as proteins or polysaccharides can be used to produce nanometer-sized particles [Chang and Chen 2005, Gupta and Gupta 2005, Ritzoulis et al. 2005]. Using aggregative (net attraction) or segregative (net repulsion) interactions, a single biopolymer separates into smaller nanoparticles. The nanoparticles can then be used to encapsulate functional ingredients and release them in response to distinct environmental triggers. One of the most common components of many biodegradable biopolymeric nanoparticles is polylactic acid (PLA). Widely available from a number of manufacturers, PLA is often used to encapsulate and deliver drugs, vaccines, and proteins, but it has limitations: it is quickly removed from the bloodstream, remaining isolated in the liver and kidneys. Because its purpose as a nanoparticle is to deliver active components to other areas of the body, PLA needs an associative compound such as polyethylene glycol to be successful in this regard [Riley et al. 1999].

NANOLAMINATES

Nanotechnology provides food scientists with a number of ways to create novel laminate films suitable for use in the food industry. A nanolaminate consists of 2 or more layers of material with nanometer dimensions that are physically or chemically bonded to each other. Nanolaminates can give food scientists some advantages for the

preparation of edible coatings and films over conventional technologies and may thus have a number of important applications within the food industry. Edible coatings and films are currently used on a wide variety of foods, including fruits, vegetables, meats, chocolate, candies, bakery products, and French fries [Morillon et al. 2002, Cagri et al. 2004]. These coatings or films could serve as moisture, lipid, and gas barriers. Alternatively, they could improve the textural properties of foods or serve as carriers of functional agents such as colors, flavors, antioxidants, nutrients, and antimicrobials. The basic functional properties of edible coatings and films depend on the characteristics of the film-forming materials used for their preparation. The composition, thickness, structure, and properties of the multilayered laminate formed around the object could be controlled in a number of ways, including changing of the type of adsorbing substances in the dipping solutions, the total number of dipping steps used, the order that the object is introduced into the various dipping solutions, the solution and environmental conditions used (pH, ionic strength, dielectric constant, temperature, etc.). The driving force for adsorption of a substance to a surface would depend also on the nature of the surface and the nature of the adsorbing substance and it could be: electrostatic, hydrogen-bonding, hydrophobic interactive, thermodynamically incompatible, etc.

NANOFIBERS AND NANOTUBES

Two applications of nanotechnology that are in the early stages of having an impact on the food industry are nanofibers and nanotubes. Because nanofibers are usually not composed of food-grade substances, nanofibers have only a few potential applications in the food industry. Produced by a manufacturing technique using electrostatic force, nanofibers have small diameters ranging in size from 10 nm to 1000 nm. As advances continue in the area of producing nanofibers from food-grade materials, their use will likely increase. As with nanofibers, the use of nanotubes has predominantly been for non-food applications. Carbon nanotubes are popularly used as low resistance conductors and catalytic reaction vessels. Under appropriate environmental conditions, however, certain globular milk proteins can self-assemble into similarly structured nanotubes [Graveland-Bikker and Kruijff 2006, Graveland-Bikker et al. 2006].

TECHNOLOGIES FOR THE DELIVERY OF ACTIVE NUTRACEUTICAL/FUNCTIONAL INGREDIENTS IN FOODS

Their goal is to improve the functionality of these ingredients in food systems. New functional ingredients are increasingly integrated into the food matrix development process [Haruyama 2003]. Bioavailability and the ability to disperse these compounds are typically higher than that of their traditionally manufactured counterparts. Encapsulation is the isolation of the active ingredient within the food product using food-grade materials. Formulation encompasses the structuring of the active ingredient, often on molecular or nanoscale levels using food-grade ingredients interacting with the active ingredient. Processing conditions will affect activity of ingredient in question. New microencapsulation technologies are relentlessly devised and invented by academics and industrial researchers.

REGULATIONS CONCERNING THE SAFETY OF NANOPRODUCTS

There are currently no special regulations for the application or utilization of nanotechnology in foods in the United States (FDA) and Europe (EFSA) [Scientific Opinion... 2009]. The U.S. Food and Drug Administration states that it regulates “products, not technologies”, and anticipates that many products of nanotechnology will fall under the jurisdiction of multiple centers within FDA and will therefore be regulated by the Office of Combination Products. FDA says that “particle size is not the issue” and stresses that new materials, regardless of the technology used to create them, will be subject to the standard battery of safety tests. In contrast to the FDA view on particle size, a recent report by the Institute of Food Science and Technology (IFST) – a United Kingdom – based independent professional qualifying body for food scientists and technologists states that size matters and recommends that nanoparticles be treated as new, potentially harmful materials until testing proves their safety.

CONCLUSIONS

As developments in nanotechnology continue to emerge, its applicability to the food industry is sure to increase. The success of these advancements will be dependent on consumer acceptance and the exploration of regulatory issues. Food producers and manufacturers could make great strides in food safety by using nanotechnology, and consumers would reap benefits as well. More and more companies are conducting research in nanotechnology and its application to food products and as more of its functionalities become evident, the level of interest is certain to increase.

In addition to the scientific and technical advances needed to continue the application of nanotechnology to foods, regulatory considerations (including safety/toxicology and environmental impact), economics and consumer acceptance of nanotechnology will ultimately dictate its success in food applications. Agricultural producers and food manufacturers could gain a more competitive position through the application of nanotechnology, and in the long term, consumers may benefit from the advances in nanotechnology that contribute to a competitive and innovative domestic agricultural and food system and provide new methods to improve safety and nutritional value of food products.

REFERENCES

- Bilska A., Rudzińska M., Kowalski R., Kryztofiak K., 2009. The effect of soy hydrolysates on changes in cholesterol content and its oxidation products in fine – ground model sausages. *Acta Sci. Pol., Technol. Aliment.* 8, 3, 15-22.
- Cagri A., Ustunol Z., Ryser E.T., 2004. Antimicrobial edible films and coatings. *J. Food Prot.* 67, 833-848.
- Chang Y.C., Chen D.G.H., 2005. Adsorption kinetics and thermodynamics of acid dyes on a carboxymethylated chitosan-conjugated magnetic nano-adsorbent. *Macromol. Biosci.* 5, 3, 254-261.

- Chen H., Weiss J., Shahidi F., 2006. Nanotechnology in nutraceuticals and functional foods. *Food Technol.* 60, 3, 30-36.
- Flanagan J., Singh H., 2006. Microemulsions: a potential delivery system for bioactives in food. *Crit. Rev. Food Sci. Nutr.* 46, 3, 221-237.
- Garti N., Benichou A., 2001. Double emulsions for controlled-release applications: progress and trends. In: *Encyclopedic handbook of emulsion technology*. Ed. J. Sjoblom. Marcel Dekker, New York, 377-407.
- Garti N., Benichou A., 2004. Recent developments in double emulsions for food applications. In: *Food emulsions*. Ed. S. Friberg, K. Larsson, J. Sjoblom. Marcel Dekker, New York 353-412.
- Garti N., Spornath A., Aserin A., Lutz R., 2005. Nano-sized self-assemblies of non-ionic surfactants as solubilization reservoirs and microreactors for food systems. *Soft Matter* 1, 3, 206-218.
- Garti N., Shevachman M., Shani A., 2004. Solubilization of lycopene in jojoba oil microemulsion. *J. Am. Oil Chem. Soc.* 81, 9, 873-877.
- Golding M., Sein A., 2004. Surface rheology of aqueous casein-mono-glyceride dispersions. *Food Hydrocoll.* 18, 3, 451-461.
- Graaf van der S., Schroen C.G.P.H., Boom R.M., 2005. Preparation of double emulsions by membrane emulsification – a review. *J. Membr. Sci.* 251, 1-2, 7-15.
- Graveland-Bikker J.F., Kruif de C.G., 2006. Unique milk protein based nanotubes: food and nanotechnology meet. *Trends Food Sci. Technol.* 17, 5, 196-203.
- Graveland-Bikker J.F., Schaap I.A.T., Schmidt C.F., de Kruif C.G., 2006. Structural and mechanical study of a self-assembling protein nanotube. *Nano Lett.* 6, 4, 616-621.
- Gupta A.K., Gupta M., 2005. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. *Biomaterials* 26, 18, 3995-4021.
- Haruyama T., 2003. Micro- and nanobiotechnology for biosensing cellular responses. *Adv. Drug Deliv. Rev.* 55, 3, 393-401.
- IFST Trust Fund. 2006. Nanotechnology information statement. Available from: <http://www.ifst.org/uploadedfiles/cms/store/attachments/nanotechnology.pdf>.
- Jasińska M., Dmytrów I., Mituniewicz-Małek A., Wąsik K., 2010. Cow feeding system versus milk utility for yoghurt manufacture. *Acta Sci. Pol., Technol. Aliment.* 9, 2, 189-199.
- Maynard A.D., Aitken R.J., Butz T., Colvin V., Donaldson K., Oberdörster G., Philbert M.A., Ryan J., Seaton A., Stone V., Tinkle S.S., Tran L., Walker N.J., Warheit B., 2006. Safe handling of nanotechnology. *Nature* 444, 267-269.
- McClements D.J., 2004. *Food emulsions: principles, practice and techniques*. CRC Press Boca Raton.
- McClements D.J., Decker E.A., 2000. Lipid oxidation in oil-in-water emulsions: impact of molecular environment on chemical reactions in heterogeneous food systems. *J. Food Sci.* 65, 8, 1270-1282.
- Morillon V., Debeaufort F., Blond G., Capelle M., Voilley A., 2002. Factors affecting the moisture permeability of lipid-based edible films: a review. *Crit. Rev. Food Sci. Nutr.* 42, 67-89.
- Riley T., Govender T., Stolnik S., Xiong C.D., Garnett M.C., Illum L., Davis S.S., 1999. Colloidal stability and drug incorporation aspects of micellar-like PLA-PEG nanoparticles. *Colloids Surf. B*, 16, 147-159.
- Ritzoulis C., Scoutaris N., Papademetriou K., Stavroulias S., Panayiotou C., 2005. Milk protein-based emulsion gels for bone tissue engineering. *Food Hydrocoll.* 19, 3, 575-581.
- Scientific Opinion of the Scientific Committee on a request from the European Commission on the Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety. 2009. *The EFSA J.* 958, 1-39.

NANOTECHNOLOGIE W PRZETWÓRSTWIE ŻYWNOSCI I MIĘSA

Streszczenie. W pracy zwrócono uwagę na ewolucję w nanonauce i nanotechnologiach z perspektywy globalnej oraz ich potencjalne zastosowanie w systemach związanych z żywnością, również w przetwórstwie mięsa. Nanotechnologia ma korzenie w wykładzie, który w 1959 r. wygłosił fizyk Richard Feynman dla Amerykańskiego Towarzystwa Fizyki. Nanonaukę odnosi się do właściwości składników rozpatrywanych w nanoskali, a nanotechnologię odnosi się do procesu lub procesów stosowanych w produkcji i/lub bioprodukcji nowych materiałów na poziomie nanoskali. Nanotechnologia oferuje duże możliwości związane z rozwojem innowacyjnych produktów i zastosowań w systemach żywnościowych. Funkcjonalna żywność, nutraceutyki, składniki bioaktywne, żywność fermowa itd. są najnowszymi przykładami dziedzin, w których może być ona wykorzystywana. Nanotechnologia i nanomateriały są naturalną częścią produkcji żywności i konwencjonalnych środków spożywczych, ponieważ charakterystyczne właściwości wielu z nich są oparte na składnikach wielkości nanometra. Działami, w których nanotechnologie mogą być wykorzystywane w przetwórstwie mięsa, wywołując istotne zmiany, są: inteligentne pakowanie mięsa i produktów mięsnych, bioaktywne peptydy pochodzące z mięsa, pro- i prebiotyki włączane do produkcji wyrobów mięsnych, nanoemulsje tłuszczowe dostarczające antyoksydanty, nanosensory i nanoznaczniki wykorzystywane w systemach bezpieczeństwa oraz nanostrukturalne produkty mięsne o określonej funkcji. Nowe horyzonty nanotechnologii w nauce o mięsie mogą być uzyskane przez dalsze badania struktur o charakterze nanoskali i metody pozwalające na kontrolę interakcji między pojedynczymi molekułami. Jednakże należy wspomnieć, że nanotechnologie i nanomateriały wymagają regulacji prawnych i oceny pod względem ich bezpieczeństwa, gdyż niektóre nowe materiały spośród nich nie były nigdy pod tym względem testowane.

Słowa kluczowe: nanotechnologia, nanomateriały, nanożywność, produkty innowacyjne, cząsteczki bioaktywne, przepisy prawne i bezpieczeństwo nanoproduktów

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