Challenges in Food Nanoscale Science and Technology

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ABSTRACT

Nanotechnology allows for the possibility to manipulate and modify material and systems on the nanoscale to produce altered characteristics that may differ greatly from those on the macroscale. The potential applications of nanoscale science and technology in the food area are emerging in such areas as safety testing, packaging, authenticity/authentication, and product development through novel functional ingredients and nutrient delivery systems. However, as with all new technologies, it is these potentially new and unique properties that will require rigorous safety testing and risk/benefit analysis to ensure that public and environmental concerns are addressed. The latter will be of particular importance to research in food science and technology at the nanoscale level if products and/or technologies will ever become commercially viable and socially/environmentally accepted. This article briefly addresses some developments and issues for nanoscale science and technology: definitions, applications, education/communication strategies, risk assessment/management activities, and public perception/acceptability.

Key words: nanotechnology, food safety, smart packaging, functional ingredient, regulatory approval, consumer perception, risk

INTRODUCTION

Nanotechnology is undeniably a source of scientific innovation that is both extensive and rapidly expanding. Driving factors for the advancement of innovation in this broad field include the desire to continually miniaturize information technology components, as well as the desire or need to strategically position future research(1) in the path of technological advancement. The term nanotechnology has garnered tremendous interest due to its promise in myriad applications. Not only are there nanotechnology undergraduate and graduate degrees offered at various universities globally(2), but educational tools for children are also available, e.g., Nanooze; (nanooze.org) and Nanowerk (nanowerk.com). Nanomaterials include nanofilms/coatings, nanotubes, and nanoparticles (NPs)(3), and the huge list of uses include plant pigments, cutting tools, resistant coatings, pharmaceuticals, drugs, paints, cosmetics, biosensors, detectors, drug delivery vehicles, wound healing and functional designer fluids, nano-electronics, nano-power sources, and ultra sensitive sensors(4). There are currently 806 identified ‘nano’ products, produced by 484 companies, located in 24 countries(5).

Nanoparticles have the potential to revolutionize the food industry from production to processing, packaging, transportation and storage(3). Certain metal nanoparticles are potent antimicrobial agents that can kill foodborne pathogens; nanosensors offer new ways to detect pathogens(6) as well as other microbes, gases or chemical contaminants in complex food matrices(7); and nanoencapsulation can facilitate nutritional fortification of foods with nutrients(8) and nutraceuticals(9). Recent food-related nanotechnology reviews have been published on food packaging(10), nutrition(8), health and safety(11), delivery systems(12), ingredient encapsulation(13), potential risks involving nano-silver(14), as well as general reviews(15-18). Although tremendous potential benefits have been identified, attention has also come in the form of regulatory and public concerns regarding safety and environmental effects. The uncertainty surrounding consumer acceptability likely contributes to the lag of nanotechnology commercialization relative to basic research(7). Possibly magnifying or contributing to such concerns is an inability to understand nanoscience in general among non-experts, and also an unwitting dilution of the term ‘nanotechnology’ itself to include concepts that are not related to one another and/or relevant, thereby further confusing non-experts as to what is and is not nanotech.

DEFINING THE FIELD

The two principal parts to defining what is to be considered nanotechnology relate to scale and uniqueness/novelty: For the regulatory purposes of the U.S. Food and Drug Administration, nanotechnology is the understanding and control of matter at dimensions between approximately 1 nm to 100 nm where unique phenomena enable novel applications(19). The European Commission (EC) recently altered its recommended defi-

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nition of nanotechnology (for regulatory purposes) to focus on particle size alone[20]. The invocation of the 1 - 100 nm dimension scale is essentially ubiquitous; it is used by the National Nanotechnology Initiative (USA); Environmental Protection Agency (USA); European Scientific Committee on Consumer Products; European Commission; Health Canada; International Organization for Standardization; Organization for Economic Cooperation and Development's Working Party on Nanotechnology and Working Party on Manufactured Nanomaterials; National Cancer Institute (USA); and American National Standards Institute. Although an upper limit of 100 nm is generally held for nanomaterials definitions, there is no scientific evidence to qualify this value with respect to unique properties, as concluded by the EC[20]. The International Organization for Standardization (ISO) also recognizes that health and safety considerations associated with intentionally produced and incidental nano-objects are not strictly contained to dimensions under 100 nm[21]. Presently, ISO offers a process for identifying, evaluating, addressing, making decisions about, and communicating the potential risks of developing and using manufactured nanomaterials[22]. From a strict research viewpoint, the definitions and terminologies of regulatory bodies are not particularly relevant to nanoscience itself; however; public perception and political action are always important in the realm of food science and technology endeavours. In this context, we suggest that length-scale classification could unduly impede progress among the various promising nanotechnologies due to mistaken associations across technologies for health safety and environmental issues.

PUBLIC PERCEPTIONS OF RISK

Possibly, the general public could accept and reap the benefits of nanotechnology without understanding their underlying principles[23]. However, there exists a perception that public engagement is important in policy making despite a lack of scientific understanding regarding which public engagement forms, features and conditions actually produce useful information and insights for scientists and policy makers[24]. The lack of such models and guidance has resulted in public engagements that sometimes have negative effects[24], and consumers' apparent inability to account for dosage when assessing the risks associated with nanofoods suggests that conferring other important food safety information to consumers may be difficult[7]. As a topical lesson for consideration among food nano scientists, a comparison of public perception of seriousness of risk for pesticides, genetic modification, high fat diet, Salmonella, and bovine spongiform encephalopathy (mad cow disease) found that the perception of risk associated with uncertainty (i.e., imperfect knowledge) was not affected by the type of risk[25]. However, significantly more seriousness of risk in the presence of uncertainty was perceived for pesticides and genetic modification, and these findings were thought to be driven by perceptions of low personal control, and high societal control and responsibility. That is, communication of uncertainty for a given risk will yield a disproportionate increase in seriousness of risk perception if it is not controllable at the individual level. Unexpectedly, the type of risk is less important whereas uncertainty itself, and believability of the information and trust in its source, are critical to risk acceptability[25].

RELEVANCE TO FOOD RELATED NANOTECH

Since the complexities and distinctions of nanotechnology risks cannot be expected to be perfectly understood (*i.e.*, uncertainty), and its use/presence can only be controlled at institutional/governmental levels, then it follows that nanotechnologies may be prone to unfavourable risk perceptions. If true then actively promoting common terminology across the broad array of existing and future areas of food nanoscience may prove to be counterproductive. It is certain that some food nano ideas/developments will not meet regulatory approval for use in food systems due to safety issues, however; even if regulatory bodies properly prevent such a case from obtaining approval, it is foreseeable that undue harm to other unrelated nanotechnologies, in terms of public acceptability, could result. It was recently predicted that a media-catalysed crisis of confidence surrounding a single nanotechnology application or product could ultimately compromise and burden the future marketability and regulation of unrelated nano products[7].

RISK, SAFETY AND CONSUMER ACCEPTABIITY

People may be more likely to accept food nanotech innovation related to packaging as opposed to direct food inclusion[23]. The high surface area-to-volume ratio of nanoparticles contributes to their high performance in food packaging applications[26]. In addition to having promising packaging roles in blocking oxygen and water vapour exchange, the incorporation of metal nanocomposites into packaging is providing new antimicrobial solutions. Such packaging is made from metal nanocomposites formed by incorporating metal nanoparticles into polymer films[3]. Silver nanoparticles have antibacterial, antimicrobial, antibiotic, antifungal and partial antiviral activity[27], and their current uses include their incorporation into clothing, food packaging, washing machines, children's toys and medical equipment[28,29]. There are currently around three times more nanosilver-based products on the market than those based on nanocarbon or nanotitanium[30]. Although useful and exciting, the incorporation of silver nanoparticles in food related applications[3,26,31] is topical to the concerns surrounding food nanotech risk perceptions, discussed above, in that some issues have arisen. Multiple environmental considerations for use on a massive, extended scale must be taken into consideration since leaching into the environment with potential negative consequences have been demonstrated[27,29,30]. Several reports have indicated that Ag NPs are toxic to cells, and can alter the normal function of mitochondria, increase membrane permeability, and generate reactive oxygen species[32-34]. By contrast, useful and promising anti-pathogen nantechnology can also be both effective and without cytotoxic concerns[35], and for certain silver antimicrobial applications, nanoparticle size is critical to safety for skin contact[28].

CONCLUSIONS

The provision of safe, secure, authenticated, high quality, nutritious, shelf-stable and fortified or even therapeutic products to future generations is the promise offered by food nano scientists and technologists. While researchers are funded to understand and develop nano developments to these ends, governments and supra-governmental bodies such as the EU are tasked with their science-based regulation; however, pressures on such agencies' regulatory processes appropriately include public opinion which itself may not be as well-informed. In order for results of nanotechnology to be commercially viable and accepted by consumers, delivering on nanofood promises will depend as much on scientific and technological advancement as it will on thoroughly studying associated risks and clearly communicating their meaning. Perhaps the prudent course of action will involve a retreat from treating nanotechnologies as an entity requiring regulation, and instead move towards regulating individual end products themselves. In the end, it is the benefit and the safety of products for the consumer that are of concern to both food scientists and regulatory bodies.

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