

Guest Commentary

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Nanotechnology: Its Impact on Food Safety

Nanotechnology—what is it?

According to the National Nanotechnology Initiative, “Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale” (National Nanotechnology Initiative, 2006).

In layman’s terms, nanotechnology is the science behind the intentional creation, manipulation, and characterization of extremely small particles and macro molecules.

The chemical, physical, and biological properties of materials differ in fundamental and valuable ways from those of individual atoms, molecules, or bulk matter. Research and development activities in nanotechnology are directed toward understanding and creating improved materials, devices, and systems that exploit these new properties.

To get an idea of the size of particles that nanotechnology encompasses, consider some comparisons. A nanometer (nm) is one-billionth of a meter. A typical sheet of paper is about 100,000 nm thick, a red blood cell is about 2,000 to 5,000 nm in size, and the diameter of DNA is in the range of 2.5 nm. The size range of highest interest in the field of nanotechnology is from 1 nm to 100 nm, so nanotechnology deals with matter that ranges from one-half the diameter of DNA up to 1/20 the size of a red blood cell. This size range is comparable to that of viruses and is one-fourth the wavelength of visible light.

Not only are new companies immersing themselves in the development of nano-

products, but well-established companies such as General Motors, Hewlett-Packard, and DuPont are also jumping on the nanotechnology bandwagon.

Nanotechnology is being used in a wide variety of industries and products, from electronics to cosmetics, from self-cleaning glass to army uniforms that monitor the health of the wearer to camouflage that changes to match its surroundings. And yes, advances in nanotechnology are affecting even food products and food safety.

According to the U.S. Department of Agriculture (USDA), by 2015 the global impact of products in which nanotechnology plays a key role will be approximately \$1 trillion annually (USDA Cooperative State Research, Education, and Extension Service, 2006).

How is nanotechnology used, or how can it be used, in food safety applications?

A recent study by the University of Toronto Joint Centre for Bioethics ranked 10 nanotechnology applications that are currently in development and have the greatest potential to aid the poor. Agricultural-productivity enhancement ranked second in this study (Salarnanca-Buentello, Persad, Court, Martin, Daar, & Singer, 2005). It would seem then that the possibility of using nanotechnology to maximize agricultural productivity is huge.

As of March 8, 2006, 212 products or product lines were using nanotechnology, of which 19 were food and beverage products (Woodrow Wilson International Center for Scholars, 2006a).

The food industry is under intense pressure to ensure food safety and at the same time to achieve increased profit margins, and is beginning to see the possibilities that

nanotechnology offers along the supply chain, from farm to table. The current drive towards optimum productivity is likely to continue to boost nanotechnology funding. A recent study from Helmut Kaiser Consultancy, which looked into nanotechnology in the food industry, estimated that the nano-food market will surge from \$2.6 billion (as of 2005) to \$20.4 billion in 2010 (Helmut Kaiser Consultancy, 2005).

Potential applications include agricultural production (plant and animal), food processing, and manufacturing in areas such as pathogen detection, food engineering, packaging, and equipment.

To illustrate the breadth of potential nanotechnology applications, let’s look at a few examples:

Pathogen Detection

Outbreaks of disease have resulted in export bans and the collapsing of markets. Japan, for example, banned U.S. beef and beef products after a single case of bovine spongiform encephalopathy (BSE) was detected in an eight-year-old cow imported into the United States from Canada. Japan is continuing to show resistance to fully reopening its borders. In the United Kingdom, the BSE crisis in the late 1990s led to a 40 percent decline in domestic beef sales and the complete loss of many export markets (Atkinson, 2007).

Scientists at the Kopelman Laboratory at the University of Michigan are developing non-invasive bioanalytical nanosensors that could perhaps be placed in a cow’s saliva gland to detect a single BSE prion particle long before the prion has had a chance to multiply and long before any symptoms of

the disease are evident (DiscussionNews Media, 2006a).

We are all too familiar with the morbidity and mortality associated with *E. coli* infections. In the Jack in the Box outbreak in 1993, 400 people were infected, and three children died of *E. coli* O157:H7 poisoning, as a result of consuming undercooked hamburgers containing the bacterium.

Scientists at the University of Rochester Medical Center have demonstrated a new technology that rapidly and accurately detects *E. coli* bacteria. The technology uses a protein from the *E. coli* bacterium, a silicon chip, and a digital camera as part of its sensing system. The protein on the chip binds with any *E. coli* in the sample being tested. Once this binding has occurred, the surface of the chip is changed. The digital camera photographs this change for analysis and confirmation of detection (Biology News Net, 2006).

A portable device has been developed that would simultaneously detect numerous toxins, pathogens, and chemicals in foodstuffs. The process involves using nanowires and antibodies in such a way that a single test will be able to identify the presence, type, and concentration of contamination. Specific pathogen antibodies are attached to the individual nanowires, which are then placed on the food. If, for instance, the food product contains *Salmonella*, the *Salmonella* cells will bond with the *Salmonella* antibody on the nanowire. The nanowires are then exposed to fluorescent antibodies, which in turn are exposed to make the bacteria visible. Scientists have dubbed this process “sandwich immunoassay” (DiscussionNews Media, 2006b).

Food Engineering

Canola oil has been engineered to help reduce cholesterol through a technology called nano-sized self-assembled structural liquids (NSSA). Minute compressed micelles (a micelle is an aggregate of surfactant molecules dispersed in a liquid colloid) serve as a liquid carrier of healthy components that are insoluble in water or fats. These micelles are called nanodrops. They are added to food product and are able to pass through the digestive system untouched, so that they proceed directly to the absorption site, carrying phytosterols to the larger micelles produced by the body. The phytosterols inhibit transportation of cholesterol from the digestive system into the bloodstream (Woodrow Wilson International Center for Scholars, 2006b).

Nanotechnology is used in the diet industry to permit chocolate lovers to enjoy their chocolate without the burden of excess sugar. NanoClusters™ are a nanosize powder that combines with foods to increase wetness and absorption of nutrients in the foods. Cocoa is added to these clusters to enhance the taste and benefit of this food (Woodrow Wilson International Center for Scholars, 2006c).

Packaging

One aim of innovative packaging solutions is the reduction of spoilage. Production, processing, and shipment of food products could be made more secure through the use of nanosensors for pathogen and contaminant detection. Silver, a well-known anti-microbial agent, is being infused into storage containers to retard bacterial growth and allow for longer storage of foods. In a case study, the 24-hour growth of bacteria was reduced by over 98 percent because of the silver nanoparticles (Woodrow Wilson International Center for Scholars, 2006d).

Nanomaterials are being developed with enhanced mechanical and thermal properties to ensure better protection of foods from exterior mechanical, thermal, chemical, or microbiological effects. Nanocomposites, for instance, are nanoparticles bonded in polymers so that the materials have enhanced properties such as lighter weight and better recyclability, as well as spoilage and flavor issues. Nanocomposite materials are currently being used in beer bottles; allowing for a 6-month shelf life (A to Z of Nanotechnology, 2006).

As milk begins to spoil, various changes occur in its molecular properties. Researchers are hoping to use these changes to react with nanoparticles embedded in the milk cartons, resulting in a change of color of the carton. It would then be easy for retailers and consumers to tell if the quality of the milk has diminished (A to Z of Nanotechnology, 2006).

Equipment

Edible oil cooks food by transmitting heat to the objects being cooked. As this cooking process continues, peroxides are formed. The peroxides are then transformed into secondary substances, which result in cooking oil with a higher viscosity and foul odor.

A catalytic device for refining frying oil is now available. This device is made of silver-infused ceramic pellets and is designed to capture the peroxides produced during the frying process and turn them into stable compounds, thereby eliminating the development of subse-

quent secondary substances. The elimination of the secondary substances prevents fatty and sticky residues from forming on the surface of the cooked foods and thus prevents the foul odors commonly associated with used oil (OilFresh Corporation, 2005).

Refrigerators are now being designed with nano silver technology that makes use of the anti-microbial properties of silver. Nanoparticles of silver are impregnated into the vegetable compartment, meat compartment, and water-dispensing system. Researchers at the University of California–Davis have verified that meat freshness and nutritional content can be maintained for up to 15 days in these compartments (A to Z of Materials, 2006).

Food Security

In addition to measuring crop productivity, tiny nanosensors offer the possibility that pathogens on crops and livestock could be monitored, making these sensors potentially useful as food security “watchdogs.” In a 2004 report, however, the Swiss insurance company SwissRe warned that nanoproducts could also increase the ability of potentially toxic substances such as fertilizers to penetrate deep layers of the soil and travel over greater distances. This possibility raises concerns about groundwater contamination as well as food contamination (A to Z of Nanotechnology, 2007).

So what’s being done to ensure that this nanotechnology is “safe?”

The above examples are illustrations of the ways in which nanotechnology may provide us with potentially safer, healthier foods, but a number of questions remain to be answered. For example, our conventional knowledge about health effects of chemicals and materials, which is based on their chemical and physical properties, may not be applicable when we are dealing with nanoproducts. The size of these products alone may alter their interaction with biological systems and affect toxicokinetic and toxicodynamic applications.

The toxicity of bulk silver, for example, does not help predict the toxicity of nanoparticles of that same material. Other issues, such as accumulation in the environment and in the food chain, remain unknown. And yes, what about the possibility (remote as it may be) of “gray goo”—nanorobots acquiring the ability to self-replicate?

Assessing the role of nanotechnology and guiding its direction will require participation from all stakeholders—scientists, industry, government, public, and others. Informed

debate is essential if we are to avoid the kind of polarization that has been seen over the issue of genetic modification. Unless rapid action is taken to address concerns about the technology, research into nanotechnology could very well progress faster than systems can be put in place to regulate its applications and their uses.

Several organizations are already involved in nanotechnology research, regulations, and guidelines; I discuss their activities below.

The Food and Drug Administration (FDA) has provided its perspective on nanotechnology on its Web site (<http://www.fda.gov/nanotechnology/>). One important fact to remember is that the FDA regulates products, not technologies. The Web site makes the following observations about issues FDA anticipates in the regulation of nanotechnology products:

1. "The likelihood that many of the nanotechnology products that the Agency regulates will be combination products (i.e., drug-device, drug-biologic, or device-biologic products).
2. Because FDA regulates products based on their statutory classification rather than the technology they employ, FDA's regulatory consideration of an application involving a nanotechnology product may not occur until well after the initial development of that nanotechnology.
3. Because FDA has limited regulatory authority over certain categories of products, the Agency may have limited authority over the use of nanotechnology related to those products. For example, there is no premarket approval of cosmetic products or their ingredients, with the exception of color additives" (FDA, 2006).

With respect to requirements necessary for obtaining FDA approval, the agency states: "Existing requirements may be adequate for most nanotechnology products that we will regulate. These products are in the same size-range as the cells and molecules with which FDA reviewers and scientists associate every day.... If new risks are identified, arising from new materials or manufacturing techniques for example, new tests or other requirements may be needed" (FDA, 2006).

The National Nanotechnology Initiative (NNI) is a federal research and development program established to coordinate the multi-agency efforts in nanoscale science, engineering, and technology. It is comprised of 26 federal agencies, including FDA, USDA, the U.S. Environmental Protection Agency, the Depart-

ment of Health and Human Services, and the Consumer Product Safety Commission.

The Nanoscale Science, Engineering, and Technology Subcommittee of NNI formed the Nanotechnology Environmental and Health Implications (NEHI) Working Group in 2005.

As FDA's associate commissioner for science put it in testimony to Congress, the purpose of the working group is to

provide for exchange of information among agencies that support nanotechnology research and those responsible for regulation and guidelines related to nanoproducs; facilitate the identification, prioritization, and implementation of research and other activities required for the responsible research and development, utilization, and oversight of nanotechnology, including research methods of life-cycle analysis; and promote communication of information related to research on environmental and health implications of nanotechnology to other government agencies and nongovernment parties (Statement of Norris E. Alderson, 2006).

The group is also working to support development of nanotechnology standards, including nomenclature and terminology, by consensus-based standards organizations.

Summary

The use of nanotechnology in the food safety industry is here—and if projections are correct, it will continue to grow rapidly over the next few years. Its potential for providing safer and more nutritious foods is important; however, there are still many uncertainties about the technology and its applications. We must make sure that the technology is safe and properly regulated to ensure maximum food safety and personal health protection. 🐞

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DAVIS CALVIN WAGNER SANITARIAN AWARD

The American Academy of Sanitarians announces the annual Davis Calvin Wagner Award. The award will be presented by the academy during the Annual Educational Conference of the National Environmental Health Association.

The award consists of a plaque and a \$500 honorarium.

Nominations for this award are open to all diplomates of the academy who:

- 1) Exhibit resourcefulness and dedication in promoting the improvement of the public's health through the application of environmental and public health practices.
- 2) Demonstrates professionalism, administrative and technical skill, and competence in applying such skills to raise the level of environmental health.
- 3) Continues to improve oneself through involvement in continuing education type programs to keep abreast of new developments in environmental and public health.
- 4) Is of such excellence to merit academy recognition.

The nomination for the award may be made by a colleague or a supervisor and must include the following:

- 1) Name, title, grade, and current place of employment of the nominee.
- 2) A description of the nominee's educational background and professional experience.

- 3) A description of the nominee's employment history, including the scope of responsibilities.
- 4) A narrative statement of specific accomplishments and contributions on which the nomination is based, including professional association activities, publications, and community/civic activities.
- 5) Three endorsements (an immediate supervisor and two other members of the professional staff or other person as appropriate).

NOMINATIONS MUST BE RECEIVED BY APRIL 15, 2008. THREE COPIES OF THE NOMINATION DOCUMENT MUST BE SUBMITTED TO:

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