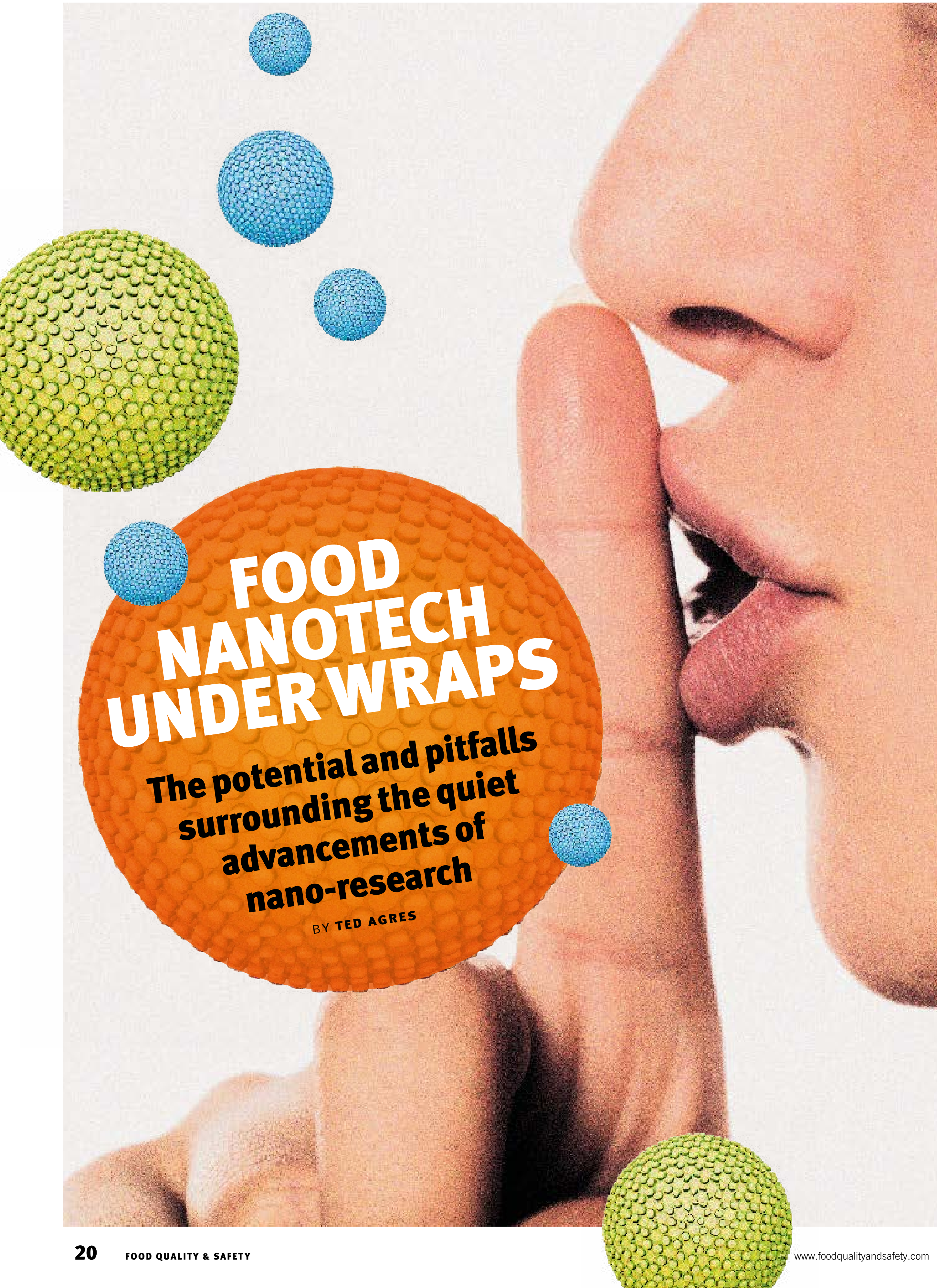


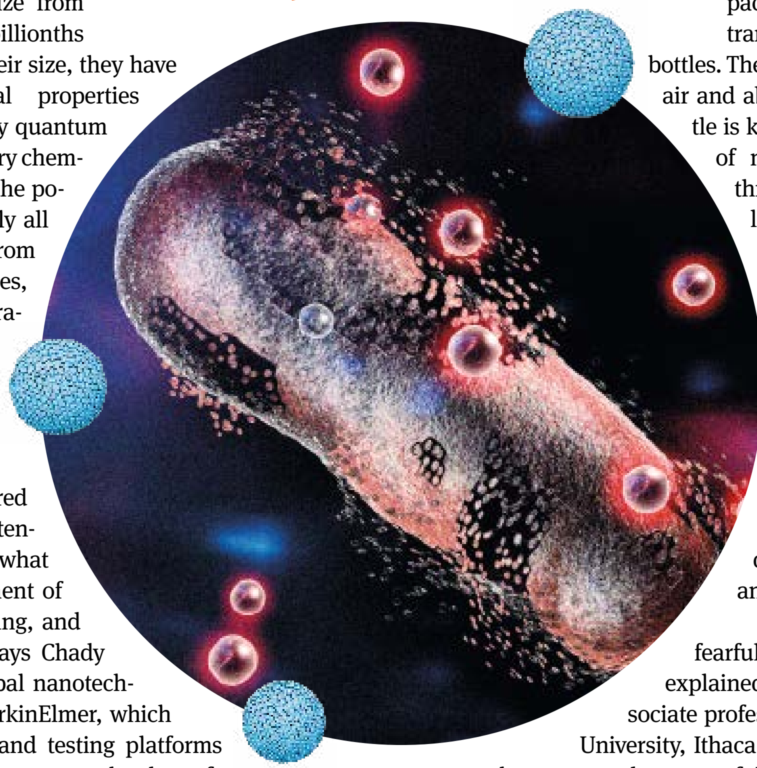
FOOD NANOTECH UNDER WRAPS

The potential and pitfalls surrounding the quiet advancements of nano-research

BY **TED AGRES**

While most major food companies publicly steer clear of nanotechnology, a large number of food and food-related items—including brand-name cereals, candy, cheese, chocolate, mayonnaise, plastic storage containers, and bottles—contain nanomaterials, added mainly to enhance color or extend shelf life. In fact, food nanotech, or the use of nanomaterials in food and food-related products, has been quietly growing over the past decade despite consumer mistrust and a lack of definitive knowledge over possible health harms.

Critics say that until the health effects are established, nanomaterials should be banned from foods or at least be strictly regulated.



Nanomaterials are engineered substances ranging in size from 1 to 100 nanometers (billionths of a meter). Because of their size, they have unique physico-chemical properties that are governed more by quantum mechanics than by ordinary chemistry. Food nanotech has the potential to enhance virtually all stages of production, from growing (nano-pesticides, nano-fertilizers), to preparation (nano-nutrients, nano-flavors), to packaging (nanofilms, nanosenor-enabled containers).

"For food and food-related science, engineered nanomaterials have the potential to transform how and what we eat through development of longer-lasting, better tasting, and safer, healthier foods," says Chady Stephan, manager of global nanotechnology applications at PerkinElmer, which manufactures analytical and testing platforms for nanomaterials. Polymer nanotechnology, for example, "can provide new food packaging materials with improved mechanical barrier with antimicrobial properties together with nano-sensors for tracing and monitoring the condition of food during transport and storage," Stephan tells *Food Quality & Safety*.

Critics say that until the health effects are established, nanomaterials should be banned from foods or at least be strictly regulated. "Scientists agree that nanomaterials create novel risks that require new forms of toxicity testing. But very little testing and regulation of these new products exists, and consumers have almost no information," says Jaydee Hanson, senior policy analyst at the Center for Food Safety.

Until a few years ago, Kraft Foods, Nestle, H.J. Heinz, Unilever, and other major food companies were enthusiastically pursuing food nanotech R&D, anticipating such innovations as nanoparticle emulsifiers to make food textures smoother and more uniform, nanoparticle colors and flavors to enhance appeal and taste, nanofilms and nanosensor-enabled "smart packaging" to detect, signal, and even prevent spoilage, and nanotech-enabled food contact surfaces to repel bacteria (see "Examples of Food Nanotech Applications" sidebar, p. 24). But instead of responding positively, consumers have grown wary about the safety of nanotechnology. Most major food companies have halted their food nanotech programs or are [keeping them tightly under wraps].

Chief among the health concerns is that nanomaterials in food can easily pass through biological barriers including cell membranes and cell nuclei. Nanoparticles can leach out of packaging material, such as transparent films, containers, and bottles. They can also be inhaled from the air and absorbed through the skin. Little is known about the health effects of nanomaterials as they move through the body and accumulate in tissues and organs. Research has found that some common nanomaterials, including nano-titanium dioxide (a whitening agent) and nano-silver (an anti-bacterial), can cause cellular dysfunction, including the over-production of reactive oxygen species and oxidative stress, a precursor to cellular damage, neurological disease, and cancer.

"Consumers are skeptical, even fearful of nanotechnology in food," explained Carmen I. Moraru, PhD, associate professor of food science at Cornell University, Ithaca, N.Y. "This is understandable because we do not yet fully understand the interaction of nanoscale matter with the human body—very important when nanostructures are ingested," she said during a presentation at the Cornell Institute for Food Systems Industry Partnership Program.

Despite the concerns, scores of researchers in the U.S. and worldwide are actively pursuing nanotechnology to enhance food quality and safety. They focus on two main areas: antimicrobial food packaging and food surface materials, and nanosensors capable of detecting minute levels of foodborne pathogens and toxins quickly and inexpensively.

Nanomaterials in Food Surfaces and Packaging

Dr. Moraru and her Cornell colleagues, working jointly with researchers at Rensselaer Polytechnic Institute, Troy, N.Y., have used an electrochemical process called anodization to create nanoscale

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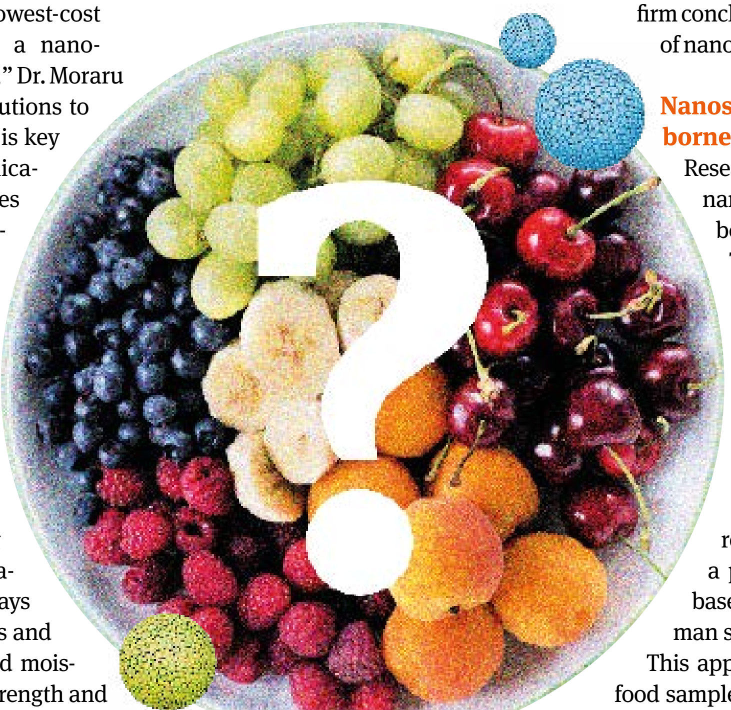
pores on metal food surfaces that prevent bacteria from sticking. The nanopores become endowed with an electrical charge and surface energy that repel bacteria and prevent biofouling and biofilm formation. The pores can be as small as 15 nanometers (a sheet of paper is about 100,000 nanometers thick). In laboratory tests, nanopores in aluminum prevented *E. coli* O157:H7 and *Listeria monocytogenes* surrogates from attaching to the metal's surface.

Researchers are also developing nanosensors to detect foodborne pathogens and toxins.



"It's probably one of the lowest-cost possibilities to manufacture a nanostructure on a metallic surface," Dr. Moraru said, noting that low-cost solutions to limiting bacterial attachment is key to nanofood processing applications. "The food industry makes products with low profit margins," she explained. "Unless a technology is affordable, it doesn't stand the chance of being practically applied."

Already widely commercialized are nanocomposites in food packaging to extend product shelf life. These include nano-silver, nanoclay (naturally occurring fine-grained silicates), and nano-zinc, among others. Nanoclays are fabricated into plastic films and coatings to strengthen gas and moisture barriers and to increase strength and toughness. Several large beer and beverage makers, including Miller Brewing Co. and South Korea's Hite Brewery, have been using nanoclay composites in their plastic bottles to create high-oxygen barrier packaging that keeps beer fresh for six months and longer.

Nano-silver is strongly anti-microbial, capable of killing more than 650 disease-causing pathogens within six minutes of contact time. As such, nano-silver is widely used in medical applications including catheters and for dressing wounds. Nano-silver has also been added to a variety of plastic food packaging and storage containers to inhibit the growth of mold and fungus. In 2014, however, the EPA banned nano-silver from food storage containers because the application had not been properly tested and registered. Nano-silver in food packaging has also been banned in many European countries. Nevertheless, such containers remain commercially available in South Korea, China, Taiwan, and other countries. Other non-food U.S. nano-silver products include socks, sportswear, laundry detergents, and deodorants.

While nano-silver is widely suspected of causing health harms, other nanomaterials, such as nano-titanium dioxide and nano-silica, continue to be used in food. Titanium dioxide is commonly used to increase the whiteness or brighten the color of numerous products including toothpaste, candy, mayonnaise, cheese, cake frostings, and yogurt. While FDA considers conventional titanium dioxide to be safe, the health effects of its nano-sized particles remain unclear. Food companies whose products have been found to contain nano-titanium dioxide deny adding the particles and suggest that they occur naturally. Nano-silica is widely used as an anti-caking agent in powdered food products and in cosmetics and skin care. The European Commission's Scientific Committee on Consumer Safety found "inadequate and insufficient" evidence to draw any firm conclusion for or against the safety of nano-silica in cosmetics.

Nanosensors to Detect Foodborne Pathogens

Researchers are also developing nanosensors to detect foodborne pathogens and toxins. The USDA's National Institute of Food and Agriculture (NIFA) last year awarded $3.8 million in grants to support nanofood R&D in food safety, food security, nutrition, and environmental protection. The University of Massachusetts in Amherst received $444,200 to develop a pathogen detection platform based on surface-enhanced Raman scattering, or SERS, mapping. This approach permits bacteria from food samples to be concentrated, identified, and quantified before any food product is shipped. The University of Georgia in Athens received nearly $500,000 to develop bio-nanocomposite-based electrochemical sensors that can detect fungal pathogens in selected crops.

"Advances in nanotechnology help secure a healthy food supply by enabling cost-effective methods for the early detection of insects, diseases, and other contaminants; improve plant and animal breeding; and create high value-added products of nano-biomaterials for food and non-food applications," says Sonny Ramaswamy, PhD, director at NIFA.

One important goal for nanotech sensors is to detect foodborne pathogens rapidly and inexpensively. Conventional detection methods such as microscopy and nucleic acid- and immunoassay-based techniques can require large samples, long incubation times, or the need to prepare cultures. Newer techniques including polymerase chain reaction, or PCR, and other molecular diagnostic methods require undamaged DNA and reagents and rely on experienced technicians, making the overall cost high enough to limit wide-scale use.

Nanosensors may be able to overcome many of these limitations. Researchers at Technische Universität München in Germany,

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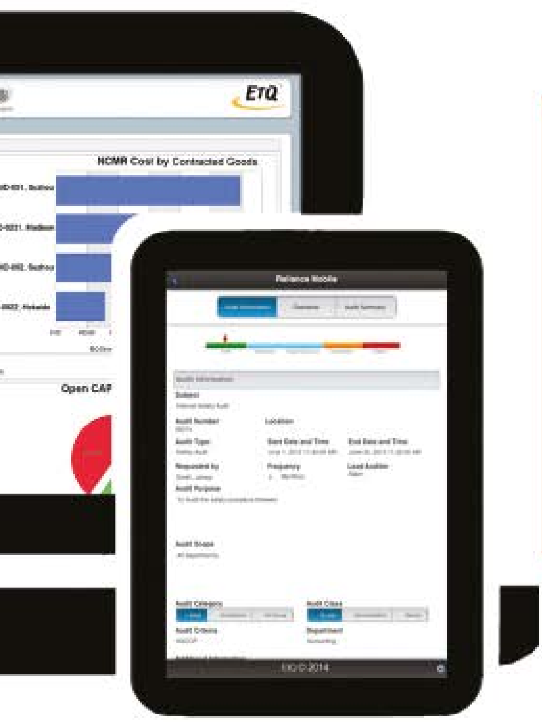

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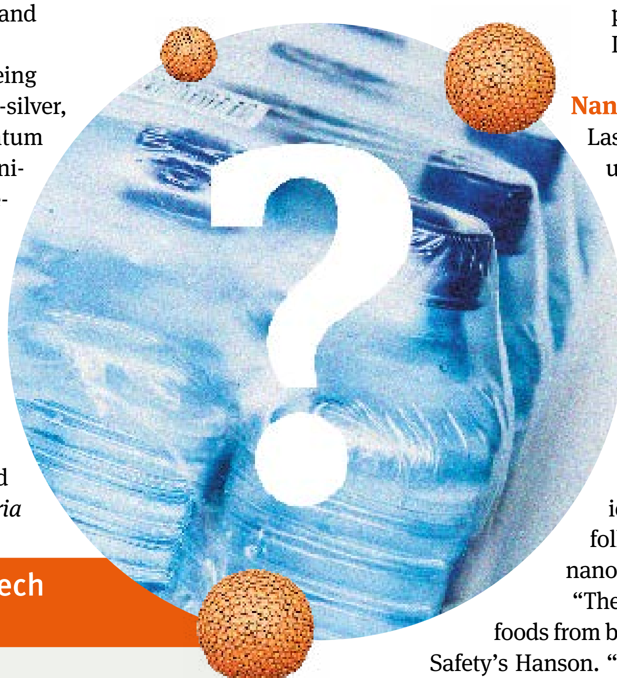
for example, are developing disposable carbon nanotube-based gas sensors that can be sprayed onto the surfaces of clear plastic packaging film. The nanosensors gauge product freshness by detecting small changes in carbon dioxide and other gases.

Laboratory nanosensors are being constructed from nano-gold, nano-silver, magnetic nanoparticles, and quantum dots. In a recently published technical overview of nanosensors, B. Stephen Inbaraj and B.H. Chen, food science researchers at Taiwan's Fe Jen Catholic University, describe a "quartz-crystal microbalance DNA sensor" to detect *E. coli*; a reusable immunosensor based on gold nanoparticles to detect *Salmonella*; and the addition of "superparamagnetic nanoparticles" coated with antibodies to detect *Listeria monocytogenes* using a high-transition temperature superconducting quantum interference device, or SQUID. Such nanosensors "provide advantages of rapid, sensitive, and user-friendly detection, enabling portability for in-field application," Inbaraj and Chen write.

Nanoparticles can leach out of packaging material, such as transparent films, containers, and bottles.



Nanofood Safety Concerns

Last year the Center for Food Safety unveiled a searchable online database of about 300 different food and food-related products found to contain more than 40 different types of nanomaterials. The products included an array of brand-name candies, breakfast cereals, seasonings, mayonnaise, as well as baby bottles and plastic storage containers. Nano-silver and titanium dioxide were the two largest categories, followed by nano-encapsulation and nano-silica.

"The FDA is failing to prevent nano-laced foods from being sold," says the Center for Food Safety's Hanson. "Our food safety agency should demand that these products be taken off the market, as companies are using food additives and food contact materials not approved at the nano scale."

After several years of deliberation, in June 2014 FDA issued industry guidance documents on nanotechnology in food. The agency said it will consider nanomaterials to be like any other food additive. While noting nanotechnology was not "intrinsically benign or harmful," its use could warrant new or additional food safety evaluations. "For food ingredients and food-contact materials, we will examine nanotechnology products for safety using our pre-existing regulatory frameworks, on a case-by-case basis," explains Marianna Naum, PhD, FDA spokesperson. "This requires that valid scientific data must demonstrate...that there is a reasonable certainty of no harm from the proposed use of the substance under its intended conditions of use," she tells *Food Quality & Safety* magazine.

Late last year, the European Commission decided to go further and published a final novel foods regulation specifying that engineered nanomaterials will require prior authorization before being used in food, with safety being assessed by the European Food Safety Authority. Food company applicants must demonstrate that they have used the most recent methods to test engineered nanomaterials. Food items containing nanomaterials will be required to disclose that information on the label.

While the regulatory science remains in flux, the genie is clearly out of the bottle. Only time and further testing will clarify the ultimate risks and rewards of food nanotechnology. ■

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Examples of Food Nanotech Applications

Food processing:

- Nanoscale coatings to prevent biofouling (bacterial contamination) of food contact surfaces
- Nanoparticles to selectively bind and remove pathogens and chemicals
- Nanoencapsulation, nanoemulsions, and nanoparticles to improve the bioavailability of nutraceuticals and deliver flavor enhancers
- Nanotubes and nanoparticles as gelation and viscosifying agents

Food packaging:

- Biodegradable nanosensors for temperature, moisture, and time monitoring
- Nanoclays and nanofilms as barrier materials to prevent spoilage
- Nanosilver and other nanoparticle surface coatings with antibacterial properties
- Fluorescent nanoparticles with attached antibodies to detect chemicals and foodborne pathogens
- Silicate nanoparticles to create lighter, stronger, and heat-resistant films

Agriculture:

- Nanocapsules to deliver pesticides, fertilizers, and other agrichemicals
- Nanosensors to detect animal and plant pathogens
- Nanosensors to monitor soil conditions, crop growth

Sources: Nanowerk, industry news releases.