# PREVENTING FOOD-BORNE ILLNESS

**ACS MEETING NEWS:** Nanomaterial-based sensors might enable farmers and consumers to detect food pathogens in real time

LAUREN K. WOLF, C&EN WASHINGTON

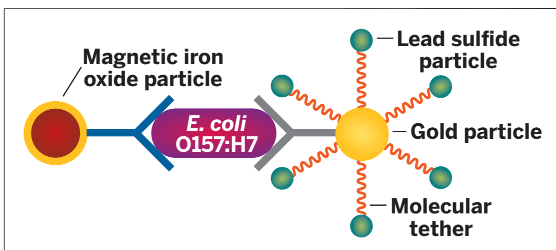
**BEGINNING IN JULY 2011,** 33 people died and more than 110 others became ill across the U.S. after eating cantaloupes shipped from a farm in southeastern Colorado. It was one of the deadliest outbreaks of food-borne illness the country has ever seen.

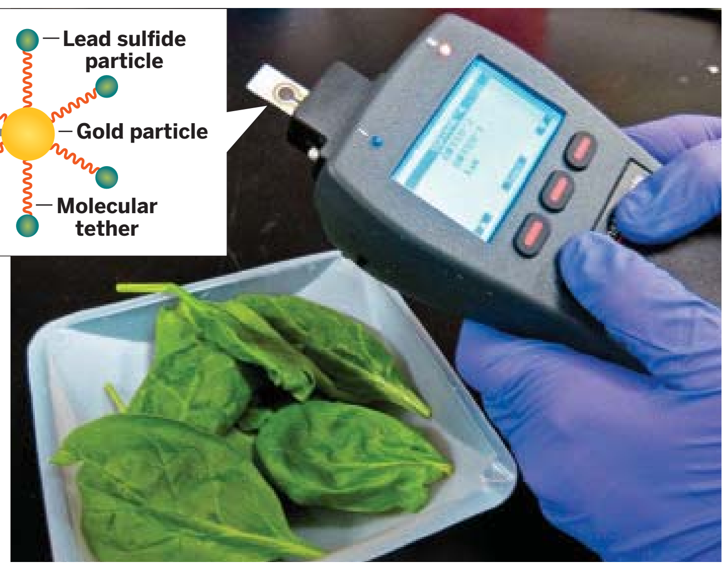
The fleshy orange melons, officials later determined, became contaminated with the bacteria *Listeria monocytogenes* at a packing facility run by family-owned Jensen Farms. An investigation conducted by the Food & Drug Administration and the Centers For Disease Control & Prevention (CDC) eventually identified dirty equipment and a missing antimicrobial wash step in Jensen's cleaning procedure as likely contributors to the outbreak. Without the chlorine-based disinfection, melons sitting in pools of rinse water on the farm's packing line might easily have spread the deadly bacteria from cantaloupe to cantaloupe.

According to Sam R. Nugen, a food scientist at the University of Massachusetts, Amherst, "If the farmers had been able to test this wash water on-site, they might have known there was *Listeria* in it." And, he hopes, they would have halted operations.

Nugen is one of many researchers who want to prevent such outbreaks by enabling farmers, food processors, and even consumers to test their food for contamination or spoilage while it's right in front of them, rather than waiting days for lab results—which often arrive too late to take preventative action.

To turn this vision into a reality, the scientists are developing small, inexpensive, nanomaterial-based devices that can simultaneously snag and tag pathogens such as *Listeria* in all types of food. The surfaces of nanoparticles can be chemically modified with various molecules that stick to pathogen targets. And when added to a food sample, the materials have unique electrical, optical, and magnetic properties that make them easy to detect, even in small amounts.



**SENSOR SANDWICH** Handheld electronic devices might someday test for contaminants in food such as spinach. The analysis chip would detect bacteria, like *E. coli*, in a liquid sample after the pathogen sticks to nanoparticles coated in two types of antibody (inset, blue and gray).

COURTESY OF VANGIE ALOCILJA

A group of nanotechnology experts, including Nugen, gathered last month at a symposium at the American Chemical Society national meeting in New Orleans to share their designs and discuss the challenges they face. "The food industry is incredibly important to the functioning of modern society," said Timothy V. Duncan, an FDA research chemist who coorganized the symposium (sponsored by the Division of Agricultural & Food Chemistry). "But it's also incredibly complex, so it's prone to failure unless we continually work to ensure that it's functioning at every point from farm to table."

Food-borne illnesses cost the U.S. roughly $152 billion per year in assorted medical bills and lost workdays, according to a 2010 report by the Pew Charitable Trusts. And CDC says contaminated food sickens one in every six Americans annually.

When farms and processing plants send water or food samples to a lab for testing, technicians typically try to grow bacterial colonies from the specimens to visually determine a pathogen's presence. In some cases, a lab might home in on a microorganism by searching for its proteins or DNA with antibody assays or amplification methods, respectively. This analysis can take days.

"By the time a farm gets results, it's probably already used the water," Nugen told C&EN. Similarly, a processor's food might be fine when samples are taken but can spoil or go stale during the waiting period.

**TO MAKE A DEVICE** that works quickly, on-site, and as accurately as tried-and-true lab instruments and methods is no small task, said Yi Lu, a chemist at the University of Illinois, Urbana-Champaign. Not only does the sensor have to be simple to use and affordable for businesses such as farms, he explained, it also has to detect dangerous microorganisms with sensitivity and selectivity similar to that achieved in the lab.

Nanomaterials' minuscule dimensions—much less than the diameter of a human hair—make it possible for nanosensors to detect pathogenic bacteria with high sensitivity, said Joseph Irudayaraj, a biological engineer at Purdue University. Bacteria are generally 1 to 3 µm in size, he said, so a slew of nanoparticles can crowd around and stick to a microorganism's outer surface, amplifying the signal they give off.

Irudayaraj, who wasn't able to attend the symposium in New Orleans, recently took advantage of this phenomenon to detect *Listeria* in milk. His research group coated iron oxide nanoparticles with an antibody specific for *Listeria*.

When mixed with contaminated milk, a number of the magnetic particles glommed onto each bacterial cell. The researchers then fished the particles and their pathogen cargo out of the liquid with a simple magnet. They detected *Listeria* in the magnet-concentrated sample via a reporter enzyme also attached to the nanoparticles. The horseradish peroxidase enzyme changed the color of small molecules the researchers added to the mix, allowing the scientists to spot as few as 97 bacterial cells per milliliter of milk in two hours (*Anal. Bioanal. Chem.*, DOI: 10.1007/s00216-013-6742-3).

Although this level of detection isn't yet as good as that achieved by bacteria-growing methods, Irudayaraj said, it's better than that of most commercial immunoassays for bacteria, which can't detect fewer than 100,000 cells per mL.

**ANOTHER VIRTUE OF** nanomaterials' small size is their high surface-to-volume ratio, said Evangelyn (Vangie) C. Alocilja, a biosystems engineer at Michigan State University. This parameter enables scientists to densely pack a particle's surface with many different types of capture molecules. Alternatively, it allows them to attach myriad signal-amplifying substances, a scheme Alocilja takes advantage of in her lab.

In New Orleans, Alocilja described her team's efforts to build a portable nanosensor for *Escherichia coli* O157:H7, an illness-inducing bacterium often found in ground beef. The group designed a three-part pathogen-sensing scheme for testing food.

The first part is a magnetic iron oxide nanoparticle coated with an antibody against *E. coli* O157:H7. The second is a gold nanoparticle coated with a second antibody to the pathogen, plus lead sulfide spheres tethered to the gold via short molecular chains. When the third part, the pathogen, is present, it brings together the other two in a sandwich complex. To detect the pathogen in beef juice, for instance, Alocilja's team magnetically pulls the three-part complex out of the liquid. Using a handheld electronic device, the researchers can detect the *E. coli* O157:H7 electrochemically via the lead sulfide spheres. Only when all three parts of the "sandwich" stick together is detection possible. So far, Alocilja said, the team has been able to detect just 10 pathogen cells per mL of sample with the method.

Nugen, the UMass food scientist, has also detected extremely low levels of *E. coli* with a signal amplification approach. His team chemically attaches magnetic

## "Imagine extracting bacteria from peanut butter. It's not easy."

nanoparticles to bacteria-infecting viruses called bacteriophages. Once these phages bind to *E. coli*, the researchers magnetically remove both microorganisms from the sample being tested. They then wait while the viruses replicate, which creates a lot of signal, even though there may have been only a few bacteria in the original sample. Although his team is still confirming its results, Nugen estimated that the technique can pinpoint fewer than 10 *E. coli* cells per mL of sample in under an hour.

Putting all these elegant nanomaterial-based detection schemes into a neat sensor package is the next challenge for this still-nascent research community. Scientists want their food safety nanosensors to be as compact and easy to use as pregnancy tests, glucose meters, and other successful medical diagnostics.

These devices have it easier than food sensors, though, because they have limited substances to deal with, Alocilja said. "You have blood serum, plasma, or urine," she said. But with foods, there's an A-to-Z range of substances to contend with.

"Imagine extracting bacteria from peanut butter," she added. "It's not easy."

Outbreaks of food-borne illness, though, are so devastating to the food industry and consumers that scientists will keep pushing toward a solution. Alocilja thinks some of these nanosensors for food safety might make it to market in two to three years. And with the New Orleans symposium organized by FDA staff, it's apparent federal agencies are supporting the effort.

"To ensure that human beings have access to safe food is one of the most sacred and important tasks performed by any government," FDA's Duncan said. "Any emerging technology that can make that job easier is a technology worth putting time and resources into." ■