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Keeping Food Safe *from* Farm *to* Fork

looking into futures

Keeping Food Safe from Farm to Fork

Each year, about 76 million people in the United States get sick from contaminated food. According to the U.S. Food and Drug Administration's **Bad Bug Book,** more than 50 bacteria, viruses, parasites and toxins are considered foodborne pathogens, including the so-called "Big Three" of bacterial food contaminants: *Listeria monocytogenes*, *Salmonella* and *E. coli* O157:H7.

Seventy-six million sounds like a lot of people, but the U.S. food supply is considered one of the safest in the world.

Since 2007, consumer confidence in the safety of the country's food supply has been steady, with about 47 percent of Americans expressing confidence in the safety of their food, according to a study that the International Food Information Council conducted this year. People who didn't think the food supply was safe dropped from 24 percent in 2009 to 18 percent in 2010; people who had no opinion rose from 26 percent to 35 percent during the same time period.

A survey done by Michigan State University scientists in 2006 found that 54 percent of Americans said they thought about food safety when grocery shopping, and 46 percent said they considered it when eating out at a restaurant.

In this issue of *Futures*, you can read about innovative research being done by MAES scientists — some of the country's leading food safety experts — and one-of-a-kind facilities and lab equipment available on campus that are helping to keep your food safe as it travels from farm fields to your table.

Starting at the very beginning of the supply chain, MAES researchers have developed sensors and other technologies to detect pathogens in food and water before any processing begins. Other MAES scientists are working with food processors, packagers, shippers and retailers to figure out where contamination can potentially happen as food begins its journey from farm to fork. The scientists then create and test new tools, technology and models to keep pathogens out and destroy any that can't be removed before processing and packaging.

MSU also is home to one of only five biosafety level 2 pilot processing facilities in North America, which was partially funded by the MAES. The highly specialized lab space allows scientists to test control methods for *E. coli*, *Salmonella* and other level 2 organisms such as *Shigella* and certain mycotoxins. The MSU facility is open to a wide range of testing and equipment that is routinely (and carefully) moved in and out to accommodate research needs.

We hope you enjoy this issue of *Futures* on some of the research to keep food as safe as possible and that it helps you understand a little more about the Michigan Agricultural Experiment Station and the research it funds. If you have comments about this issue or would like to subscribe (it's free!), send a note to *Futures* Editor, 109 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, or send an e-mail to osowskiv@msu.edu. You also can call 517-355-0123.

For the latest information about MAES research and events, I invite you to subscribe to the free MAES e-mail newsletter. Sign up by visiting the MAES Web site at www.maes.msu.edu/news.htm. You also can view this and past issues of *Futures* on the Web site by clicking on the "research publications" link.

— Jamie DePolo

Erratum

In the winter/spring issue of Futures *in an article entitled "Turf's Up," the research and ideas of Joan Nassauer, professor of landscape architecture at the University of Michigan, were unintentionally misrepresented in a statement made by MAES turfgrass scientist Thom Nikolai. Dr. Nikolai apologizes to Dr. Nassauer for oversimplifying and therefore misrepresenting the objective of her study in Flint, Mich. The statement at issue has been corrected in both the online winter/spring edition and all remaining hard copies.*

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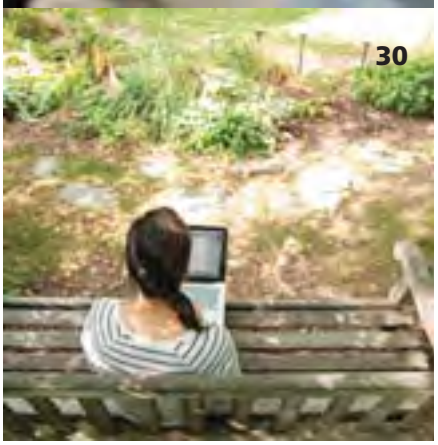

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Identifying

Since 2007, consumer confidence in the safety of the country's food supply has been steady, with about 47 percent of Americans expressing confidence in the safety of their food, according to a study by the International Food Information Council conducted this year. People who didn't think the food supply was safe dropped from 24 percent in 2009 to 18 percent in 2010; people who had no opinion rose from 26 percent to 35 percent during the same time period.

A survey done by Michigan State scientists in 2006 found that 54 percent of Americans said they thought about food safety when grocery shopping, and 46 percent said they considered it when eating out at a restaurant.

Everyone who thinks about food safety probably owes a debt of gratitude to MAES food science and human nutrition and microbiology and molecular genetics scientist Jim Pestka for developing the first rapid detection kit for vomitoxin, officially known as deoxynivalenol (DON), a member of the trichothecene class of toxins that are produced by fungi in food and the environment. DON is produced by mold in wheat and barley when they're exposed to excess moisture or become infected with fusarium head blight, a disease that's also called scab. A scab outbreak doesn't always mean DON is present, but there is a strong association between the disease and the toxin. ››

Invisible Invaders

By creating new sensors and discovering biomarkers, two MAES researchers are working to keep food safe at the molecular level.

In both pictures, Sylvia Vetrone *(left)* and Jessica Ochoa (center) work with Vangie Alocilja in her lab on sensor development. Vetrone is a Whittier College faculty member and Ochoa is a student at the California school. They were in Alocilja's lab for 10 weeks this summer doing biosensor research; the visit was funded by the U.S. Department of Homeland Security-Minority Serving Institution Program. In the picture at right, Alocilja's son John Daniel is on the far right. He was a summer research intern in her lab.

> "What we want to do is find a balance between food safety and having enough food."

DON also is produced in corn during gibberella ear and stalk rot. Because of rainfall and late harvest last season, the 2009 corn crop in Michigan and other Great Lakes states was severely contaminated with DON, which restricted international sales.

Pestka's test kit technology was licensed by the Lansing company Neogen and is sold worldwide as a first line of defense against mold toxins.

Twenty years later, Pestka is still studying DON, but now he's trying to determine exactly how the toxin affects humans. The research has taken on added significance in light of the recent spike in wheat prices: from July to August 2010, prices climbed more than 70 percent. The increase was due in part to severe drought in Russia, which has ruined crops and caused the country — the world's largest wheat exporter — to announce it was temporarily banning exports of the grain. Shortages are feared.

"We're trying to figure out the true risk of exposure to DON using animal models to predict what will happen in people," Pestka explained.

Scab-infected grain has been associated with food poisoning symptoms in people: nausea, abdominal pain and dizziness that appear about 30 minutes after eating the grain. There is no link between DON and cancer. Other research shows that low levels of DON in pigs (0.05mg/kg body weight) can cause the animals to vomit. This level of exposure equates to a 175-pound person ingesting 0.00014 ounces (4 mg). In the United States, U.S. Food and Drug Administration regulations limit DON levels to 1 ppm (parts per million) in cereal-based food. Europe has stricter standards, allowing only 200 ppb (parts per billion) in infant foods, one-fifth of the U.S. level. Canada's regulations are similar to those of the United States, but the country is considering adopting DON standards that parallel European levels. If Canada does adopt European standards, it could mean that some farmers lose markets for their grain.

"What we want to do is find a balance between food safety and having enough food," Pestka said. "We want to ensure that food is safe, but we also don't want to limit the food supply. The goal of this work is to find out if stricter standards are actually producing safer food."

As part of a two-pronged approach, Pestka is studying biomarkers of DON's effects in mice. After DON exposure, mice grow less and put on less weight; Pestka has identified hormones called insulin growth factors that are tied to weight gain and is examining how DON affects these hormone levels. After he maps this relationship in mice, he'll use it as a model for people.

In the United Kingdom, his colleagues are studying biomarkers of DON exposure, tracking metabolites produced by the toxin in the urine of pigs and mink. The more DON consumed, the higher the urine metabolite level, a relationship the scientists also think holds true in people.

"We know that DON doesn't cause cancer, that it affects the neuroendocrine system — which controls appetite — and can cause vomiting," Pestka explained. "There have been outbreaks of acute gastrointestinal illness in people in Japan, China and India after people ate fusarium-infected grains. Those outbreaks were

MAES food science and human nutrition and microbiology and molecular genetics scientist Jim Pestka developed the first rapid detection kit for vomitoxin, a toxin produced by fungi that attack corn and other crops.

associated with DON. But we don't know the long-term effects of ingesting a small amount of DON over time, and we also don't know the effects of ingesting a large amount just once. There are a number of variables that we need to investigate."

Pestka and his colleagues also want to identify other metabolites related to DON found in grains and the minimum level of each that causes vomiting. The scientists then will determine how the neuroendocrine system changes in response to each metabolite. In this way, they can tease apart the specific components of the toxin that cause ill effects and the severity of each one. They're also studying how the metabolites affect gastrointestinal serotonin levels. A hormone produced by the brain, serotonin can tell the body to stop eating.

Does DON Have Benefits?

Pestka also is intrigued by potential applications of DON, especially its affects on serotonin levels.

"Very, very preliminary research has shown that obese mice fed low levels of DON lose weight and body fat," he said. "Initially the mice refuse all food, but their bodies adapt and they eat about 10 percent less than they had been and maintain that lower intake level and the weight loss."

As Americans continue to fight a losing battle with bulge, the market for safe, effective weight loss products continues to balloon with waistlines. In August, the Centers for Disease Control and Prevention (CDC) reported that the number of states with an adult obesity rate of 30 percent or higher had tripled (to nine) since 2007. (Michigan's adult obesity rate is 29.6 percent.) In 2000, no state had an obesity rate of 30 percent or higher. Today, about 75 million Americans are considered obese. Obesity costs the country as much as $150 billion per year to treat related illnesses such as diabetes, heart disease and cancer.

Two Canadian scientists have developed derivatives of DON that they say have toxicity removed and patented these for weight loss. Though the product isn't for sale, they were convinced the idea had possibilities and wanted to protect their work.

Pestka is studying how DON works at the molecular level to understand more about how its toxicity can be separated from any beneficial effects.

"We have to figure out the risks and the benefits and weigh them accordingly," Pestka said. "There are many helpful drugs derived from bacteria and fungi that also have toxic effects. Penicillin comes from *Penicillium* mold. Botox is made from a toxin produced by the bacterium *Clostridium botulinum*, which is the same toxin that causes botulism. If we can verify the safety of DON derivatives, we may be able to develop drugs that have possible benefits for people."

Mapping Mold Mechanisms

Pestka's focus on DON is a more specific aspect of his research on how 200 trichothecenes function at the molecular level, which is funded by a National Institutes of Health grant. Trichothecenes bind to ribosomes (the structures in cells that make proteins) and interfere with gene regulation, and that makes the immune system function less effectively.

Trichothecenes' effects on gene regulation mimic the effects of shiga toxin and ricin, two serious health threats. Shiga toxin is produced by several strains of *Escherichia coli*, including *E. coli* O157:H7, and is mainly spread through contaminated food. Shiga toxin affects the lower GI tract

> "The goal of this work is to find out if stricter standards are actually producing safer food."

and causes bloody diarrhea, ulcerative colitis and hemolytic uremic syndrome, which can lead to renal failure or chronic kidney disease. Each year, shiga toxin sickens more than 100,000 people and leads to 3,000 hospitalizations and 90 deaths. There are no vaccines to prevent shiga toxin illness and no treatments besides staying hydrated. Antibiotics can make the illness more severe.

Ricin is a potent toxin naturally found in castor beans, which are processed worldwide to make castor oil. Ricin is part of the leftover mash when the oil is extracted and can be in the form of a powder, mist or pellet, or dissolved in water or weak acid. Ricin can kill a person 36 hours after exposure; if a person hasn't died five days after exposure, he or she usually recovers. There is no antidote. Ricin is considered an agent of biological warfare and is classified as a category B (second highest) bioterrorism agent and national security threat.

"The trichothecenes seem to affect gene regulation in the same way that shiga toxin and ricin do," Pestka said. "If we can understand how trichothecenes work at this level, we may be able to develop treatments or antidotes for the other compounds, which would diffuse them as health and national security threats."

Sensing Pathogens

National security also drives much of the research done in the lab of Evangelyn "Vangie" Alocilja, MAES biosystems engineering scientist.

"The Sept. 11 attacks underscored the need for biodefense for the nation's food supply chain," she said. "From farm to table, there are numerous vulnerabilities where food and water can be contaminated with bacteria and other pathogens. The aim of our lab is public protection."

Her work focuses on nanostructured biosensors, sensors that use biological receptors — antibodies, enzymes and nucleic acids — to detect the presence of specific pathogens. By immobilizing the bioreceptors on thin wafers of metal or membrane and attaching the sensor to a computer, scientists can observe in real time when the receptors bind to the target pathogen and send an electrical signal to the computer that alerts them that the pathogen is present.

Alocilja works at the nano level — one nanometer is one-billionth of a meter — using extremely tiny nanoparticles, nanotubes, nanomagnets and nanopores to build her sensors.

"Moving to the nanoscale level is like going from a 10-lane highway to a one-lane road," she said.

Alocilja and her team have developed and applied for patents on 20 biosensors *(see box page 9)*, including mechanisms to detect *E. coli*, *Salmonella*, *Mycobacterium tuberculosis* and *Bacillus anthracis*, the bacterium that causes anthrax, as well as sensors that can detect various viruses, including the influenza virus. Most of her biosensors are aimed at detecting pathogens classified as category A or B (the two highest levels) bioterrorism agents by the CDC.

"Detection mechanisms need to be rapid, accurate and sensitive at very low levels," she explained. "Detection and identification of pathogens such as *E. coli* O157:H7 and *Salmonella* still rely heavily on conventional culturing techniques. You take a sample that is considered to be contaminated and grow the culture

Barbara Cloutier, a doctoral student in the Department of Large Animal Clinical Sciences, also does research on biosensors in the lab of Vangie Alocilja.

in the lab to see if the pathogen is there. It can take from two to seven days to get results, which can be a long time in many cases.

"For TB, it's even longer," Alocilja continued. "Culturing the tuberculosis bacterium takes at least four weeks. Our sensor has results in less than two hours, so people can start treatment much faster. My philosophy is 'bring diagnosis to the field — or people.'"

In developing countries, where people may have to travel for several hours to get to a medical clinic, being able to have results without a second trip to the clinic may mean that many more people get treatment, which can be the difference between life and death.

Most of Alocilja's biosensors look like computer chips and can be used to test food, water and clinical samples. Most of her sensors detect a single pathogen, but some can detect multiple pathogens or strains of pathogens. Her influenza biosensor, for example, is aimed not just at detecting the flu virus but at determining whether the strain is pandemic.

"Biosensors are novel for health, food, water and agricultural biodefense issues," she said. "In the '80s and '90s, much of the biosensor work was done for medical applications. The first one developed was a glucose test. But the research has progressed rapidly. We've developed sophisticated, user-friendly tests; there is a lot of potential for biosensors.

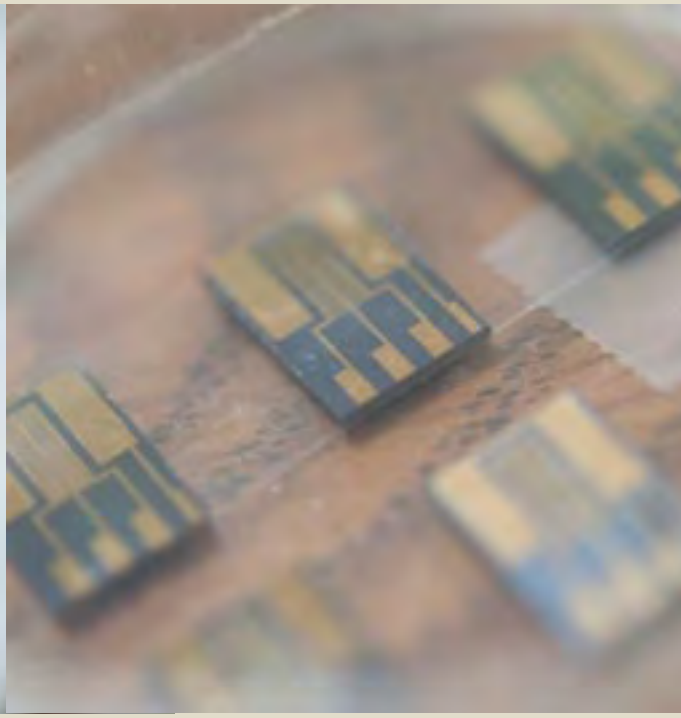
"Detection is a niche area," she concluded, "but it's very exciting to know that this work can save lives. I'm very happy and motivated to come to work each day — I have a big smile on my face."

— Jamie DePolo

Biosensors Developed in Evangelyn Alocilja's Lab

1. **Electronic nose**
2. **Membrane strip biosensor for detecting bacteria and viruses**
3. **MEMS-based interdigitated silicon immunosensor for detecting *E. coli* O157:H7**
4. **Nanoporous silicon immunosensor for detecting *Salmonella* and *E. coli***
5. **Nanoporous silicon-DNA biosensor for detecting adenoviruses**
6. **Molecularly imprinted polymer based biosensor for detecting theophylline**
7. **Polypyrrole DNA biosensor for detecting *E. coli***
8. **Biologically modified electrically active magnetic nanoparticles (nano-BEAM) for rapid extraction and concentration of target analyte**
9. **Nano-BEAM-glycan biosensor for detecting emerging pandemic influenza viral strains**
10. **Electrospun nanofiber-based immunosensor for detecting bacteria and viruses**
11. **Biobarcode DNA biosensor for detecting the pagA gene of *B. anthracis* (the bacterium that causes anthrax) and the lel gene of *Salmonella***
12. **Nano-BEAM-DNA biosensor for extracting and detecting the pagA gene of *B. anthracis***
13. **Biobarcode copolymerization biosensor for detecting *B. anthracis***
14. **Nanoparticle (magnetic-gold) DNA biosensor for detecting tuberculosis**
15. **Nanoparticle (magnetic-polyaniline) immunosensor for detecting *B. anthracis* and *E. coli* O157:H7**
16. **Magnetic resonance based biosensor for detecting bacteria**
17. **Bioluminescent sensors for detecting various contaminants**
18. **G-protein coupled receptor (GPCR) based biosensor for detecting chemical toxicants**
19. **RFID-based biosensor for product protection**
20. **Magnetic nanoparticles for rapid target extraction**

Most of the sensors developed in Alocilja's lab look like computer chips and can be used to test food, water and clinical samples.



food safety in the real world

SPECIALIZED EQUIPMENT AND LAB SPACE, AS WELL AS BROAD EXPERTISE,

ALLOW MAES SCIENTISTS TO OFFER FOOD SAFETY SOLUTIONS TO FOOD COMPANIES.

MAES

MAES FOOD ENGINEERING SCIENTIST KIRK DOLAN IS internationally recognized for his research on thermal processing techniques (what most non-food engineers might call "cooking"), so he knows his thermally processed food statistics. People in the United States eat 31 percent more packaged food than fresh food, and they consume more packaged food per person than people in almost all other countries. Americans' plates are full of processed and ready-to-eat meals such as frozen pizza, microwave dinners, and sweet or salty snacks. The more than 28,000 food manufacturing companies in the United States employ about 1.5 million people.

Just about any food that comes in a package — cookies, pasta, candy, cereal, juice, milk, tuna, potato chips, ketchup, salad dressing — is thermally processed. The U.S. Department of Agriculture (USDA) estimates that each American ate about 787 pounds of processed food in 2009.

Dolan's thermal processing research focuses on maintaining food safety while optimizing nutrients in food. He creates mathematical models and statistical analyses of thermal processes to figure out the best cooking time/temperature combinations and to determine the effect of heat on the pathogens that could possibly contaminate the food, as well as on the nutrients in the food.

"Often the decision is made to cook at a higher-than-needed temperature to absolutely ensure the safety of the food," Dolan explained. "But that can lower the nutritional quality of the food. What I'm doing is giving food manufacturers scientific tools so they can maximize nutrition and be certain the food is as safe as it can be."

During the past 10 years, Dolan has upgraded all the thermal processing equipment in his lab, so he's using machines and techniques that parallel industry set-ups. U.S. Food and Drug Administration (FDA) officials were so impressed with his lab that they've approached him about hosting and teaching a two-week advanced course on the topic for their employees.

Dolan has a background in both engineering and food, and his models apply to processing lines that operate continuously, which are more complicated than small-batch processors that run a line for a few hours or a day and then switch to a different product. He's currently developing models to kill *Salmonella* in extruded dry food products (cereals, dog food, snack foods, etc.), an area of emphasis for the USDA and FDA. (An extruder is a basically a giant press that squeezes dough out in specific product shapes such as puffs, tubes, squares and stars.) In August, several varieties of Iams and Eukanuba dry dog food were recalled because some products were potentially contaminated with *Salmonella*. Besides infecting pets, research has shown that people, especially young children, can get sick from the tainted food by petting sick animals or touching dirty pet food dishes and then putting their hands in their mouths.

> "It's hard to escape thermally processed food."
>
> —KIRK DOLAN

Working with Muhammad Siddiq, visiting associate professor of food science and human nutrition, Dolan also has developed models for cherry juice processors to track anthocyanin levels in the juice. Anthocyanins are compounds in plants that give fruits and vegetables their red, purple and blue colors. Anthocyanins are powerful antioxidants, and research has shown that they may help reduce the risk of heart disease, diabetes and certain cancers.

"Dr. Siddiq was asked by Cherry Growers, Inc., a Michigan grower-owned cooperative, to help them modify their processing so the cherry juice had more anthocyanins in it," Dolan explained. "I developed a model to track the levels. We looked for ways to keep more anthocyanins in the product while maintaining its safety." ››

He's also tracked anthocyanin levels for Overby Farms, a dog treat manufacturer in Leland. The company uses tart cherries as an ingredient in its products and wanted to make sure that the levels were offering appropriate health benefits.

Dolan works with companies of all sizes and frequently is introduced to clients through representatives of the MSU Product Center for Agriculture and Natural Resources, a resource for both new and established businesses. He also mentors several graduate students and uses his industry connections in his role as unofficial career services liaison.

"There is a huge need for thermal processing scientists in industry," he said. "Our program can't graduate enough students. Their MSU training gets them great jobs as soon as they're done with the program."

Xing Out Food Pathogens

"X-ray technology has baggage, no doubt about it," said Brad Marks, MAES food safety engineer. "But there are foods for which there are really no other viable treatments, such as fresh leafy greens. Sanitizing washes work, but only to a point. They're not bulletproof, as some of the recent recalls have demonstrated."

Like Dolan, Marks collaborates with companies to solve particular food safety issues and investigate new technologies. Together with Elliot Ryser, MAES food science and human nutrition researcher, and Sanghyup Jeong, visiting assistant professor of biosystems and agricultural engineering, he began studying low-energy x-ray irradiation for pasteurizing leafy greens and almonds after Rayfresh Foods Inc., a custom builder of irradiation equipment in Ann Arbor, approached him about using the technology to kill *E. coli* and *Salmonella* bacteria on delicate baby spinach and lettuces. The company, which is using the MSU team's results to build the first commercial-sized x-ray machine for food irradiation, wanted to know the levels necessary to kill the pathogens.

"Our work has shown that x-ray technology is effective in killing the bacterial pathogens without causing undesirable changes in product quality," Marks said. "We use low-energy x-ray, which has smaller shielding requirements than other types of food irradiation."

The necessary dose is higher than a medical x-ray but lower than electron beam and gamma-ray technology. Low-energy x-ray equipment is more compact than competing technologies and could be incorporated into production lines. Food irradiation does not make food radioactive.

The FDA approves food irradiation on a product-by-product basis (it's regulated as an additive) and so far allows spinach, iceberg lettuce, ground beef, spices, poultry and shellfish to be irradiated to kill *E. coli*, *Salmonella* and other microbes. Foods that have been irradiated must display the "radura" logo as well as the statement "treated with radiation" or "treated by radiation."

"There are opportunities for breakthroughs using irradiation for food safety, especially for large-scale food operations," Marks explained. "It's a good solution for specific markets, such as bulk lettuce.

During the past 10 years, MAES scientist Kirk Dolan has upgraded all the thermal processing equipment in his lab. FDA officials were so impressed that they've asked him to teach a class for their employees.

"We know irradiation works to kill bacteria," he continued. "Economics and risk management strategies will determine if and how widespread its use becomes."

Food producers in other countries also have sought out MSU food irradiation expertise. Dolan is collaborating with researchers at the Date Palm Research Center at King Faisal University in Saudi Arabia to investigate whether irradiation can be used to kill insects that attack dates and eliminate mold. Currently the chemical methyl bromide is used to kill the insects, but the company would like to move toward non-chemical methods to ensure food safety.

One of the world's top date producers, Saudi Arabia has approximately 12 million date palms — about 12 percent of the global total.

Because there are no food irradiation facilities in Saudi Arabia, the company is shipping the dates to MSU for testing. Dolan and Siddiq, in partnership with Jeong, Karim Maredia, professor in the Institute of International Agriculture who initiated the project, and Jim Miller, MAES entomology scientist, will treat the dates with electron-beam and gamma-ray irradiation technology and compare the results. The dates will then be shipped

back to Saudi Arabia for sensory testing to discern if the irradiation has any effect on the texture or flavor of the fruit.

"The Saudi Arabian company came to us and asked for a proposal," Dolan said. "We're starting to do more and more of this type of corporate-sponsored research, which benefits both MSU and the company. There is also the possibility that the date processing company will pay for one of their employees to enroll in our doctoral program. That's another way we can work together with industry."

Keeping the Big Three at Bay

MAES food scientist Ryser, one of the country's leading microbial food safety experts, also develops food safety tools for companies, especially to control what he calls bacterial transmission of the "Big Three" in food: *Listeria monocytogenes*, *Salmonella* and *E. coli* O157:H7. Because *Listeria* can grow at temperatures as low as 37 degrees F (the average refrigerator temperature is between 35 and 38 degrees F), the bacterium can multiply when certain types of cheese, raw vegetables and deli meats are contaminated, even if they're kept cold.

Ryser and a team of 10 students conducted an experiment to determine how fast a lettuce processing line would become contaminated if a small amount of contaminated product happened to get into the mix, as well as how widespread the contamination would be.

Using a commercial-sized processing line in his lab in the Trout Building — the only processing line of its kind in the country — the researchers contaminated 20 pounds of radicchio leaves with *E. coli* O157:H7 and ran it through the processing line (shredding, washing, drying) and then ran 2,000 pounds of uncontaminated iceberg lettuce through the equipment. They sorted through the 40, 50-pound bags of greens and combed through all the bits left on the processing equipment to determine the final location of the contaminated radicchio. They found radicchio in every bag of processed lettuce and more than 200 small pieces on the processing line.

"We wanted to demonstrate how far the contaminated product can actually spread during processing," Ryser said. "This will give the processor a good idea of how much product is at risk if they do have a contamination event. The goal is to give the leafy green industry suggestions about improved equipment design, when they need to shut down the line and sanitize the entire processing line, and how much additional product may be at risk if *E. coli* O157:H7 is later found in a bag of salad greens."

To see an MSU Today video story on the *E. coli* in lettuce experiment, visit http://www.msutoday.msu.edu/shows/20/index.php?segment=3

Ryser is studying what happens to bagged salads as they travel from processor to distributor as well.

"Most bagged greens are shipped in trucks, so if there is any *E. coli* or other pathogens in the lettuce and the truck is warmer than 40 degrees, the lettuce experiences what we call 'tempera-

Safe Space Enables Cutting-edge Research

Operational for about two years, MSU's biosafety level 2 pilot processing facility is one of only five such facilities in North America. It allows scientists to test control methods for *E. coli*, *Salmonella* and other level 2 organisms such as *Shigella* and certain mycotoxins. Some of the other biosafety level 2 processing facilities are very product-specific, but the MSU facility is open to a wide range of testing and equipment that is routinely (and carefully) moved in and out to accommodate research needs.

"The MAES helped fund the facility, and the investment has leveraged $1.5 million to $2 million in grants to do work in the facility," Marks said. "We're getting very close to being financially sustainable."

The space has specialized hoods and air handling systems to ensure that no infectious agents escape. Lab manager Mike James and all other scientists and students who use the lab have had specific training on handling the pathogens. The space is also home to experimental food irradiation equipment, conveyer systems and pilot-scale ovens.

Marks and Ryser are working with Intralox, a multinational conveyer belt manufacturer, to evaluate belt materials and designs for optimal cleaning and sanitizing.

The facility has started to do more testing of bacteria, especially *Salmonella*, on dry products such as peanut butter, flours, grains and nuts.

"*Salmonella* on dry products is a very hot topic right now," he said. "First, it's harder to kill — it survives at temperatures that would kill it in meat products. So we're trying to figure out what we need to do to eliminate it. Second, not all dry products are thermally processed. California almond growers said they were going to pasteurize all their almonds to remove any threat of *Salmonella*. But pasteurizing other dry products, such as flour, is extremely challenging.

"We're so fortunate to have this facility," he added. "It allows us to do research that can't be done at most other universities."

Students Paul Sirmeyer and Tasha Breslin examine a lettuce processing line in MAES scientist Elliot Ryser's lab. Ryser and a team of students conducted an experiment to see how fast the line would become contaminated if a small amount of contaminated product got into the mix.

> "We provide support and capacity to help companies solve any… issues before they become problems."
>
> —BRAD MARKS

ture abuse,'" he explained. "In theory, bagged salads are shipped in refrigerated trucks, but there can be wide variations in temperature, which can lead to the potential growth of *E. coli* during transport."

After using radio-frequency identification (RFID) tags to monitor and record the temperature and humidity in the trucks, Ryser will recreate the situations in a programmable incubator to assess the food safety risk.

"There's very little scientific data on this," Ryser said. "We also want to study the temperatures at which bagged salads are kept in retail stores. This will provide empirical evidence so processors, distributors and retailers can assess risk and make the best decisions for food safety."

An outbreak of *Listeria* in deli meats in Canada earlier this year pushed that bacterium back into the headlines. Ryser said that listeriosis outbreaks are decreasing, but isolated incidences keep the total number of cases the same.

In collaboration with MAES food science and human nutrition researcher Ik Soon "Ike" Kang, and Al Booren, MAES food science and human nutrition and animal science researcher, Ryser is studying *Listeria* inhibitors in hot dogs, which are considered a deli meat.

MAES scientist Brad Marks *(left)* and Mike James, lab manager of the biosafety level 2 pilot processing facility, attach sensors to almond samples for a food safety experiment.

Elliot Ryser *(with glasses, back center)* works with his students on a project to demonstrate how fast contaminated product can spread in a lettuce processing line.

"The USDA gives packers three options to control *Listeria* in deli meats," Ryser explained. "They can pasteurize the product after packaging, they can add a *Listeria* inhibitor, or they can test the environment for *Listeria*."

"Many of the plants use all of these options during processed meat production," added Booren, who spends 75 percent of his time working with the meat industry. "Most of the industry adds a *Listeria* inhibitor, such as sodium diacetate and/or sodium lactate, to the product."

Many of the *Listeria* inhibitors come in liquid form, which can be difficult to mix in with meat seasoning spice blends. Manufacturers have tried to develop powdered versions, but most turn into hard pellets when mixed with water. Kang has been contacted by Kemira Chemical Solutions, a Finnish company that has developed a powdered form of sodium diacetate and sodium lactate that doesn't solidify when the mix comes into contact with water and asked to test the product's effectiveness against *Listeria*.

"They initially wanted me to test its ability to control a number of pathogens, but we decided to focus on *Listeria* first," Kang said.

"If used properly, these compounds [sodium diacetate and sodium lactate] don't change the flavor or appearance of the meat," added Booren, who has studied meats at MSU for 28 years. "They're generalists, in that they're not specific to any one pathogen. We assume they would likely inhibit *E. coli* and *Salmonella*, but that research hasn't been done yet because those bacteria are likely killed during cooking."

Kang, who worked at Kraft/Oscar Meyer Foods before coming to MSU in 2009, also is studying ways to keep poultry free from *Salmonella* and other bacteria.

In a project funded by the Midwest Poultry Consortium, Kang is comparing the effectiveness of air chilling, water chilling

Big Bad Bugs

More than 50 bacteria, viruses, parasites and toxins are considered food-borne pathogens. MSU scientists are taking aim at some of the most common.

Salmonella spp.

This rod-shaped bacterium is found in animals — especially poultry and swine — water, soil, factory surfaces, kitchen surfaces, animal feces, raw meats, raw poultry and raw seafood. The approximately 2 million to 4 million annual cases of salmonellosis in the United States cause nausea, vomiting, abdominal cramps, diarrhea, fever and headache. Cooking food thoroughly is the only way to kill *Salmonella*. Exerts also advise sanitary practices such as hand washing, separate cutting boards and knives for raw meat, and countertop disinfecting to avoid cross-contamination.

Listeria monocytogenes

Some studies suggest that up to 10 percent of people may carry *Listeria* bacteria in their intestines. It has been found in animals, birds, fish and shellfish. A hardy bacterium, *Listeria* isn't affected by freezing, drying or heat. Because most cases of listeriosis are sporadic (not linked to a major outbreak), there is limited information on the frequency of the disease. Symptoms of listeriosis include meningitis, septicemia, encephalitis, and intrauterine or cervical infections in pregnant women that can cause spontaneous abortion. About 20 percent of people who contract listeriosis die from the disease, which is associated with raw milk, soft-ripened cheeses, deli meats and smoked fish. Experts advise purchasing pasteurized dairy products, cooking food thoroughly, and using sanitary practices such as hand washing, separate cutting boards and knives for raw meat, and countertop disinfecting to avoid cross-contamination.

Escherichia coli O157:H7

E. coli is a natural inhabitant of the intestines of all animals, including people, and helpfully suppresses the growth of harmful bacteria. But the O157:H7 serotype produces large amounts of potent toxins that severely damage the lining of the intestines and can cause severe cramping, fever and bloody diarrhea. Some very young children infected with O157:H7 have developed hemolytic uremic syndrome, which can lead to kidney failure. In most cases, symptoms usually clear up after about eight days and are mild in many people, so exact case numbers aren't known. But the Food and Drug Administration (FDA) says that *E. coli* O157:H7 is thought to be second only to *Salmonella* as the cause of bacterial diarrhea in the Pacific Northwest. Undercooked or raw hamburger has been linked to many O157:H7 outbreaks, but alfalfa sprouts, unpasteurized fruit juices, dry-cured salami, lettuce, raw milk and cheese curds also have been implicated. Experts advise purchasing pasteurized dairy products, cooking food thoroughly, and using sanitary practices such as hand washing, separate cutting boards and knives for raw meat, and countertop disinfecting to avoid cross-contamination.

Campylobacter jejuni

A relatively fragile bacterium, *Campylobacter* is found in healthy cattle, chickens, birds and flies. It also has been found in non-chlorinated water sources such as streams and ponds. Campylobacteriosis causes watery (possibly bloody) diarrhea, fever, cramps, nausea, headache and muscle pain. Though symptoms usually last for about 10 days, about 25 percent of infected people have a relapse. The FDA lists *Campylobacter* as the leading cause of bacterial diarrhea in the United States and estimates that the annual number of campylobacteriosis cases exceeds the number of salmonellosis cases (2 million to 4 million). Research shows that 20 percent to 100 percent of retail chickens are contaminated with *Campylobacter*. Raw milk and non-chlorinated water have also been linked to infections. Properly cooking chicken and drinking pasteurized milk and chlorinated water practically eliminate potential exposure. Experts also advise sanitary practices such as hand washing, separate cutting boards and knives for raw chicken, and countertop disinfecting to avoid cross-contamination.

Information adapted from the Bad Bug Book on the FDA Web site

Gut Microbes May be Therapeutic Targets for Food-borne Diseases

At any given time, trillions of tiny microbes — some helpful, some harmful — are living on and in humans, forming communities and outnumbering the body's own cells by tenfold.

Using a $7.3 million federal grant that establishes a new cooperative research center at MSU, a group of investigators is studying the microbes that live in our intestines, analyzing the role they play in food- and water-borne illnesses that kill millions of people each year worldwide.

MSU's Enterics Research Investigational Network (ERIN) is one of four such U.S. research centers being funded by five-year grants from the National Institutes of Health's National Institute of Allergy and Infectious Diseases. It is led by MAES microbiologist Linda Mansfield. The team is looking at the enteric microbiome — all the microbes that live in the human gut.

"Our long-term goal is to develop new interventions and treatments for food- and water-borne diseases; we want to know what makes people more susceptible or more resistant to enteric diseases," said Mansfield, whose group is focusing on illnesses caused by *E. coli, Salmonella, Clostridium difficile* and *Campylobacter*, among others. "Evidence suggests that the enteric microbiome profoundly affects our health and disease susceptibility and may be a new preventive and therapeutic target."

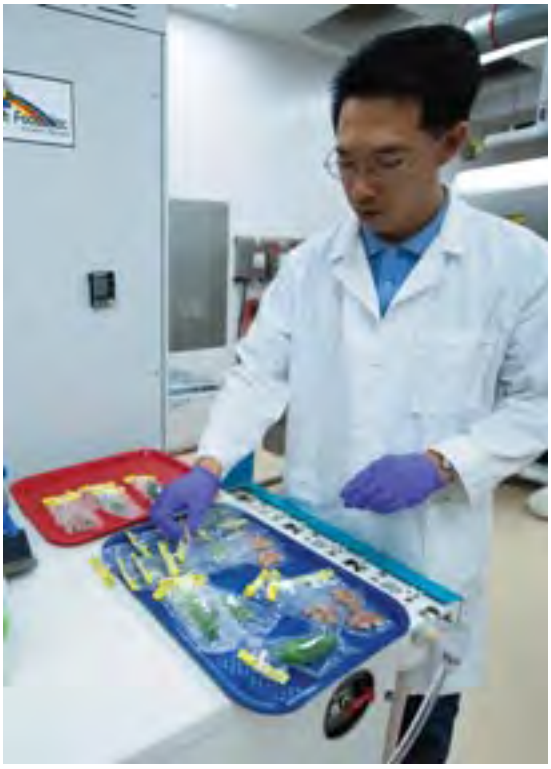
Enteric diseases, which are primarily caused by food- and water-borne pathogens, are the leading cause of acute diarrheal illness, which, despite concerted efforts, remains a continued threat in the United States, particularly among children.

Overall, investigators from the colleges of Veterinary Medicine, Human Medicine, Natural Science and Engineering as well as the Michigan Agricultural Experiment Station are taking part in the project. The research team will be looking at three specific areas:

- **Microbial ecology and pathogenesis:** Led by MAES microbiologist Robert Britton, researchers will use a bioreactor model, made by MSU engineers, and mice to study communities of microbes and whether reduced diversity in those communities — which can be caused by antibiotics — allows pathogens to take hold. "Although most of us think bacteria are bad, the 10 trillion bacteria that inhabit our gut play some very important roles, one of which is to keep bad bacteria from flourishing in our intestines, causing disease," Britton said. "What we hope to learn is which bacteria or communities of bacteria can protect us and how can we use this knowledge to create new therapies and treatments."
- **Host response:** Led by Mansfield, researchers are trying to find the link between enteric disease caused by *Campylobacter jejuni* and autoimmune disorders that are rapidly increasing in the United States. Nervous system autoimmune diseases such as Guillain Barré syndrome and Miller Fisher syndrome have been associated with recent *Campylobacter* infection. These diseases can cause paralysis and death, and researchers do not know why, Mansfield said. "Our goal in this project is to understand the causes and to develop preventions and cures," she said. "We believe it will also provide insights into how other autoimmune diseases begin."
- **Clinical research:** Led by molecular epidemiologist Shannon Manning, researchers will study fecal samples taken by the Michigan Department of Community Health to determine how infection with various pathogens (such as *E. coli*) alters the types of microbes present in the intestine. The microbial communities in patients with disease will be compared with communities in exposed individuals without disease. "Our hope is to identify potentially beneficial microbes, microbial communities and/or microbial byproducts that can be used to prevent or treat disease," Manning said.

MSU's ERIN cooperative research center continues and builds on the work started by the Microbiology Research Unit scientists. That unit is a research component of the National Institutes of Health's Food- and Waterborne Integrated Research Network.

and misting/evaporative air chilling in limiting bacterial growth, as well as the three methods' effects on carcass quality. After slaughter and plucking, poultry must be chilled to an internal temperature of 40 degrees F in 2



Research associate Sanghyup Jeong prepares lettuce, pepper and almond samples to test how well x-rays can kill pathogens.

to 4 hours. Most U.S. processors immerse the birds in water, which also has chlorine in it; most European processors use air chilling, in part because they fear any *Salmonella* on the birds will spread in the water. Also, using chlorine to kill pathogens is less accepted by European processors. Air chilling is more expensive than water chilling. Apprehension about *Salmonella* in U.S. poultry, as well as chlorine residue on the birds, means exports to Europe are almost non-existent.

"U.S. processors are interested in air chilling for several reasons," Kang explained. "There are some drawbacks to water chilling, plus air chilling would open up European markets to U.S. poultry."

While the birds are immersed in the icy bath, they absorb about 10 percent of their weight in water. Most of this extra fluid is removed immediately after chilling, but a small amount stays in the birds, even after the birds are additionally processed. Kang said about 90 percent of U.S. broilers are additionally processed, which means 10 percent are sold whole with the extra water included. Additionally, one broiler requires 7.5 liters of water for chilling. In 2009, more than 9 billion broilers were processed in the United States. That

processing used almost 100 billion liters — more than 25 billion gallons — of water, according to Kang.

"That waste water has to be treated before it can be discharged, which is expensive," he said. "So in the long run, air chilling may be more cost-effective. We're continuing to analyze the data. Our preliminary sensory tests also show that people find the air-chilled poultry to be juicier, and other research has found that people detected more flavor in the air-chilled birds."

In a related project funded by the Animal Agriculture Initiative at MSU, Kang is examining levels of *Salmonella*, *E. coli* and *Campylobacter bacteria* before and after air and water chilling on poultry.

"The industry wants this information," Kang said. "Earlier research showed the two chilling methods are equal in reducing bacteria numbers. But if we eliminate the chlorine, air chilling seems to remove more bacteria. We started the research in June, so we're still conducting experiments."

Scaling up Food Safety Solutions

"Most companies overprocess their foods, especially meats, to ensure food safety," Marks said, reiterating Dolan's point.

MAES scientists Ik Soon Kang *(second from right)* and Al Booren *(right)* teach students how to make brats in the MSU Meat Lab.

"What I do is take microbial knowledge and translate it into a food safety solution for our industry stakeholders. Then we scale that solution up in our biosafety level 2 pilot processing facility so it works for commercial companies. We're providing support and capacity to help companies solve any potential issues before they become problems."

One of only five biosafety level 2 facilities in North America, the lab allows the scientists to test control methods for *E. coli*, *Salmonella* and other level 2 organisms. *(See box on page 15.)*

More than 50 percent of Marks' research involves meat products and control of *E. coli* and *Salmonella*. Meat has a number of variables — fat content, water content, structure, type of product — and each one affects how resistant any bacteria are to heat, the one intervention that is sure to kill the pathogens.

> "The goal is always to have products and facilities with no pathogens."
>
> —AL BOOREN

In response to consumer demand for ready-to-eat or heat-and-serve meals, many processors are now offering blade-tenderized and marinated meats. But both processors and consumers need to know that these treated products have different cooking requirements than products that aren't treated.

Marks' research has shown that *Salmonella* injected into the center of a steak, in a marinade perhaps, is twice as resistant to heat as *Salmonella* that is mixed throughout ground beef. So processors have to adjust cooking times and temperatures to ensure that any bacteria are killed. Marks' tools help them do that.

As Marks develops his time and temperature combinations, Booren helps the industry implement the models and helps make sure they're successful.

"We work with the industry to test Brad's models because consumers want their food 'validated' as safe," Booren said. "We also pass along data from both the industry and our pilot facilities to him, helping him develop and validate the models. The goal is always to have products and facilities with no pathogens."

"Our end products are tools that meat companies can use to determine safety," Marks said. "We also give companies the best information possible about any uncertainty that comes into play when processes are scaled up. You can't just multiply something by 1,000 because the batch is that much bigger. It doesn't work that way. We help companies make informed decisions on maintaining the balance between safety, taste and cost."

— Jamie DePolo

MAES scientist Maria Rubino studies how packages can be used to enhance fresh produce sanitation.

Reducing Food Safety Risk in a

At the same time, MAES researcher Robb Clarke is studying how RFID tags can track food from source to store.

"Important steps must be taken to better protect the nation's food supply — from farm to fork — and to strengthen our food safety system so we prevent outbreaks from happening in the first place."

— Margaret A. Hamburg, Commissioner, Food and Drug Administration

Although "farm to fork" is a relatively easy concept to sink one's teeth into, the task of consistently delivering safe food to the consumer is becoming increasingly complex. Globalization of the food supply chain, new disease agents, outdated laws, changes in the U.S. population (a growing proportion of people 60-plus years old who are more susceptible to certain types of infections) and new dietary patterns present significant challenges to our food safety system.

Global Marketplace

Food safety is front-page news. The names of bacteria such as *E. coli* 0157:H7 and *Salmonella* are becoming household words as product recalls are more and more a part of our daily news diet. According to food safety experts, contaminated food outbreaks in the United States have more than tripled since the early 1990s, from 100 per year to more than 350 annually, and an estimated one in four Americans suffers from food-borne illness each year.

In an effort to help improve food processing technologies and minimize the risk of food-borne illness, several MAES researchers are exploring effective ways to make and keep our food supply safe. ››

Rubino *(above, left),* doctoral student Siriyupa Netramai *(above, center)* and research associate Brajesh Tripathi examine results in Rubino's lab. Rubino and MAES research Rafael Auras have a four-year project looking at how a package can become a sanitation chamber.

Fresh Produce and Food Safety: a "Package" Deal

One segment of the food supply that is causing significant concern is fresh and fresh-cut produce. According to the U.S. Department of Agriculture (USDA) Economic Research Service, fresh produce is now the leading cause of *E. coli* O157:H7 food-borne illness outbreaks in the United States. From 1996 to 2007, leafy vegetables accounted for 34 percent of all outbreaks due to microbial contamination traced back to a specific fruit or vegetable, 10 percent of the illnesses and 33 percent of the deaths. Twenty of the 24 leafy green outbreaks in the United States during the same period have been associated with *E. coli* O157:H7 contamination.

Much of the growth in the consumption of fresh leafy greens over the past decade has been associated with the sales of prewashed, bagged salads. Although such products undergo a sanitation process, it is not always sufficient to eliminate contamination. Since 1995, the Food and Drug Administration has identified 18 outbreaks caused by *E. coli* 0157:H7 associated with lettuce and two outbreaks associated with spinach. The last nine outbreaks involved packaged produce.

To help address this problem, MAES packaging researchers Maria Rubino and Rafael Auras teamed up on a four-year project, beginning in 2009, to explore how packaging might be used to complement the sanitation process for fresh cuts and vegetables.

"Our thought was that introducing packaging as an additional step in the sanitation process — the package would become a sanitation chamber — could allow for a longer and more thorough exposure to the appropriate bactericide; in the case of this project, chlorine dioxide gas," Rubino said. "If the package was used alone, it wouldn't be enough — it's the packaging within the sanitation system that makes the process effective."

Scientific studies have demonstrated the efficacy of chlorine dioxide in killing bacteria on produce surfaces. Chlorine dioxide use in sanitizing is not new — it is the primary post-harvest bactericide used in the fresh produce industry today — but its use in the gas form is relatively new.

"We know that, for chlorine dioxide to work, it has to be in direct contact with the product," Auras said. "Currently, bactericide gases such as chlorine dioxide gas are commonly applied by flashing the package head space. The gas is supposed to work its way down through the package, but it doesn't always reach all of the product."

Rubino and Auras had to clear two major hurdles before they could begin their research.

"First, produce has very small profit margins, and there would be great cost involved to change an entire packing line," Rubino explained. "That meant that we couldn't change the exterior of the packaging if we were going to work within the current system, so our only option was to modify the interior of the package.

"Second, no method existed to explore the movement of gases such as chlorine dioxide within and through packaging or to understand how it interacts with packaging materials," she continued. "We needed to know if exposure to chlorine dioxide damaged the package material or changed its characteristics in a way that compromised its ability to ensure product safety and adequate shelf life. You can't do any designing if you don't have this baseline knowledge."

From 1996 to 2007, leafy vegetables accounted for 34 percent of all outbreaks due to microbial contamination traced back to a specific fruit or vegetable.

Siriyupa Netramai, a doctoral packaging student in Rubino's lab, spent a year developing and validating a method to characterize the interaction of chlorine dioxide with packaging materials.

On the product side, collaborating scientists Bassam Annous, from the USDA, and Karl Matthews, of Rutgers University, are conducting chlorine dioxide gas treatments on lettuce, spinach and cherry tomatoes to identify dosage levels that decontaminate these produce without adversely affecting their quality.

Fortified with the information provided from these investigations, the researchers turned their attention to the development of packaging designs.

Rubino and Auras engaged engineering postdoctoral student Brajesh Tripathi to conduct computer simulations on the distribution, flow and dissipation of gases, including chlorine dioxide, in both rigid clamshell containers and produce bags. Using the results of his study, Tripathi designed a rigid container with a gas distribution insert and a produce bag with vertical reservoirs inside the bag that contain small perforations to allow for the flow of gas from the reservoir to all sections of the bag.

"We're doing this modeling to make sure that the chlorine dioxide gas will reach every space in the package and achieve a high enough reduction of microorganisms to ensure food safety," Auras said. "Produce such as lettuce and strawberries have a lot of microorganisms on their surfaces and often come in contaminated from the field. Because of their irregular surfaces, it is extremely difficult with current sanitation technology to guarantee that this produce can be completely cleaned before it reaches the consumer."

Netramai tested the efficacy of the new flexible packaging design by bagging shredded romaine lettuce contaminated with *E. coli* in one- and two-reservoir bags. The packages were flashed with chlorine dioxide gas in the reservoir areas at two dosage levels and then stored at 4 degrees Centigrade. Samples were taken from the bags at one, four and seven days.

"What we found is that, with the reservoir design, the low dose of gas accomplished almost the same level of pathogen reduction as the high dose, and the lettuce quality was significantly higher," Rubino said. "The two-reservoir bag worked better, but the one–reservoir bag was effective as well.

"The rigid container insert design works the same way as the reservoir system by channeling gas throughout the container," she added. "Experiments with these containers will be conducted using leafy greens and cherry tomatoes when the dosage concentration is determined."

The most promising container designs and treatments will be beta tested at the biosafety level 2 pilot processing facility *(see story page 13)* on campus, which enables direct application of the latest research results to real-world challenges in food safety engineering. The project team is already working on adapting commercial packaging equipment to accommodate the new approach.

MAES packaging researchers are studying how well chlorine dioxide can kill bacteria on lettuce samples.

"Ultimately, an integrated sanitizing and packaging system will be developed to further ensure the safety of fresh leafy greens and tomatoes," Rubino said. "We are hopeful that this model can eventually be used for other products."

An Ounce of Prevention and a Trail of Breadcrumbs

As the food supply chain reaches around the globe, the ability to track and trace food from source to store is paramount.

"In a food emergency, quickly identifying the source of the contamination and removing unsafe food products from retail shelves are critical," said Robb Clarke, MAES packaging researcher and head of the MSU Auto-ID Research and Testing Center. "The ability to do this largely depends upon whether a product's movement can be followed through each stage of the food supply chain, a process referred to as traceability."

RFID tags "listen" for a radio query and respond by transmitting their own unique identification code. The tags range in size from smaller than a grain of sand to as large as a wireless modem.

The MSU Auto-ID Center supports research activities related to the evaluation and improvement of automatic identification systems. Clarke and a team of graduate and undergraduate students and other MSU scientists are using the center as a focal point for real-world research and performance testing of automatic identification system components including device readers, tags, printed barcodes and optical scanners.

Radio frequency identification (RFID) — an automatic identification method that relies on storing and remotely retrieving data using tiny devices called RFID tags or transponders — is a technology increasingly being used in the agrifood industry. These devices range in size from smaller than a grain of sand to as large as a wireless modem.

Researchers Dan Grooms *(left)*, Robb Clarke *(center)* and Dan Buskirk are all studying how RFID tags can be used to reduce food safety risks. Clarke heads the MSU Auto-ID Research and Testing Center. Grooms and Buskirk are working with the beef cattle industry.

"An RFID tag is an object that can be adhered to or incorporated into a product for the purpose of identification using radio waves," Clarke said. "The tags 'listen' for a radio query and respond by transmitting their own unique identification code."

A major focus in RFID use is supply chain management — improving the efficiency of inventory tracking and management from warehouse to consumer. RFID tags are commonly used in case, pallet and shipping container tracking and truck and trailer packing in shipping yards. RFID technology can also be used to detect a product contamination problem before it hits the shelves or to help avoid safety and health hazards and massive recalls.

"High-profile incidents of food-borne illness and deaths have raised public awareness about food safety," Clarke said. "The use of automatic identification for food safety is driven largely now by issues surrounding recalls."

Although Clark and his team spend much of their time on the component reliability and process control of RFIDs, they are also investigating other aspects of the technology.

"Over the past year, we've been exploring how much energy a tag uses to read information and what materials might block the flow of energy, causing, for example, a false positive response," Clarke said. "A tag can activate and send a signal, but it may not have the energy it needs to get the information to the reader. Or a tag may be blocked by some material and not be able to activate."

Water and metals cause significant difficulties with RFID technologies, especially in the ultra-high frequency spectrum, Clarke said.

"Water, in essence, absorbs energy; metals reflect it," he said. "We're not trying to change the physics of RFID reading but work within the boundaries of physics to bend the rules a little bit. For example, we can use metal to increase our read rate and read range by bouncing the signal off metals and directing it to places where we don't have a direct line of sight."

Clarke said that the center's work has also contributed to the development of RFID systems designed to work in a water-laden environment.

"During some of our earlier work on tagging of beef packages for retail distribution, we conducted an experiment that showed that, if there were meat trays stacked in a cooler, the reader could read an RFID tag only on the top tray — it couldn't read through even to the next tray below because the water in the meat tissue blocked the signal," he explained. "But if those same trays were frozen, the reader could capture information five or six trays deep, so we learned that RFID signals can penetrate ice crystals."

Clarke and members of his lab also wrote some tagging software for use at an archeological dig site in Greece to help inventory finds.

"One site that I visited had 11 universities digging there at various times of the year, and the groups kept discovering the same artifacts and entering them into the master database multiple times," Clarke said. "This technology will prevent these groups from 'discovering' the same piece over and over again.

"We also found that this inventory software program is perfect for small to medium enterprises, such as retail stores or cattle lots," he said. "For example, when a cow herd is delivered, the recipient can use a reader to count each cow as it comes off the train or truck and get an exception report to determine if there are any cows missing."

A third area being investigated by center staff members concerns opportunities around the use of nanomaterials for inks.

"There are situations where you can use very small amounts of nanomaterials in a substrate — be it paper or plastic — that allows for conductivity," Clarke said. "Nanomaterials can also be used to create printable tag material, which is faster, more cost-effective and more environmentally friendly than conventional copper etching processes, which involve taking a sheet of copper and chemically removing layers until the desired thickness is reached.

"Most people who are going to help expand the use of RFID tagging are looking for a competitive advantage," Clarke continued. "For food suppliers, that means technologies that will allow them to capture and analyze data quickly, so that they can make informed decisions on the spot with science-based numbers behind them. From a food safety standpoint, anything we can do to prevent these types of outbreaks of foodborne illness should be a priority. Auto-ID technology is an essential part of the solution."

Tag, You're It. Tag, You're Not It.

An excellent example of the use of automatic identification technology to ensure food security and safety is the use of RFID tags in the Michigan beef cattle industry. MAES large animal scientist Dan Grooms is working with MSU animal science colleague Dan Buskirk to enhance food safety through implementation of animal identification.

"Michigan currently has a mandatory RFID system for cattle, put in place primarily to help control and eradicate bovine tuberculosis," Grooms said. "All cattle, before they leave a farm, must have RFID tags. The tag — a small, button-shaped device that is attached to an animal's ear — carries a passive, low-frequency radio transmitter with a unique 15-digit number embedded in a microchip. This is their 'social security number' and, should anything happen to that animal, it can be traced back to where it originated."

The biggest problem with this tag is that the RFID reader has to be very close to the tag — between 4 and 30 inches – to get information off of the microchip, Grooms said. Each button also has to be read individually.

"These factors make it very difficult to use these tags for managing large groups of animals on farms or at auction markets," he said.

To address this challenge, Grooms and Buskirk are working with researchers at North Dakota State University (NDSU) who are using an ultra-high frequency RFID system, which is embedded in a bangle ear tag.

Michigan has a mandatory RFID system for cattle that aims to help control and eradicate bovine tuberculosis. All cattle must have RFID tags attached before they leave a farm. Grooms and Buskirk are testing ultra-high frequency RFID tags that can be used to read a herd as it's being loaded into a truck.

Grooms *(left)* and Buskirk *(right)* are testing an ultra-high frequency tag that may replace current cattle RFID tags. Clarke *(center)* is investigating materials that may block RFID signals.

"These tags can be read by antennas that are 10, 20, 40 feet away from the cattle," Buskirk said. "Cattle can actually be read all at once as they're running down an alleyway or being loaded onto a truck – it is much more user-friendly."

The tags are currently being tested at the MSU feedlot.

"The first version of the tag we tested was a complete failure," Grooms said. "By the end of the study, only 10 percent of the tags worked. We just finished testing a newer version this year, and 100 percent of the tags were readable at the end of the study, so we think we have a tag that's pretty durable and reliable. It could replace the current tag."

Grooms and Buskirk are also using the new tag to explore other ways to take advantage of this animal identification technology.

"Besides just having an ear tag that does nothing until something may go wrong with an animal, we wanted to explore potential uses that would enhance the track-and-trace process," Grooms said. "For example, when an animal comes to eat that activity is recorded. If the animal doesn't show up to eat, that is known as well. Then our managers can say, 'That animal is not eating — is there something wrong?' Being aware of this situation allows us to follow up on this animal to determine if there is actually a problem.

Grooms, Buskirk and NDSU researchers will continue to test the bangle tag in various feedlot environments and sale yards, and when loading and unloading trucks.

"Unique animal identification is essential and is the backbone of any disease surveillance, production and performance system," Grooms said. "Developing field-based models for objectively comparing various technologies will help improve animal health, animal welfare, product quality and, most importantly, food safety."

Making a World of Difference

Reducing food risk in the global food supply system will require a combination of innovative technologies, practices and policies that recognize the complexity of the global marketplace, and the ability to translate increased awareness and knowledge into action.

"In the past, packaging was used solely for transport of products," Rubino said. "Making the package part and parcel of the sanitation process could be an efficient, cost-effective way to take the produce industry to the next level of food safety. Advances in our research will provide novel and creative strategies that could be expanded to other commodities throughout the produce industry, significantly enhancing consumer well-being and product shelf life."

"It is very important to have production systems that have safe incoming product and adequate sanitation processes so that products are safe when they reach the consumer," Auras added. "These recurring outbreaks of food-borne illness underscore the need to develop approaches and practices that will ensure the microbial safety of these products."

In addition to packaging and process enhancements, tracking and traceability play key roles in food safety and security.

"Automatic identification systems allow you to collect information, manage it rapidly and make decisions quickly," Grooms said. "These and other risk-based technologies are critical to facing current and future food safety challenges."

Buskirk concurs.

"There's just really no way to improve on animal health and food safety without the identification of products through the system," Buskirk said. "That's what we're really talking about – a way to put a name on each item so that we're able to track and trace."

According to Clarke, reducing food safety risk around the globe depends on our collective ability to gather science-based, actionable data at every link of the food supply chain.

"It doesn't matter whether you're talking about artifacts in a field in Greece, cattle in a feedlot or a package of food in a store," Clarke said. "Tagging is about collecting information. An effective food safety system requires the ability to identify risks and take action before they harm people."

— Val Osowski

RESEARCH IN ACTION

Cutting-edge research and **outside-the-box thinking** have firmly established **MSU's reputation in the global food safety arena.** As a result of that name recognition, **MAES scientists are working with companies** large and small around the world to **translate food safety research into action.**

MAES food safety scientist Les Bourquin flips through the many slide decks and photos from the food safety symposia he has conducted: Bulgaria in 1999 and 2000, Romania in 2003, India in 2004-2010, plus China and Rwanda in 2009. And those are just the international courses. The domestic classes would take up three times as much space. An expert on HACCP (hazard analysis and critical control points), a food safety management system endorsed by the U.S. Food and Drug Administration and the U.S. Department of Agriculture that analyzes food safety at various points in the processing and distribution chain to control biological, chemical and physical hazards in food, Bourquin and his science-based curricula are in demand.

"MSU has name recognition in the area of food safety," he said. "It's created more demand for our research and training. We're the only university that works with the Global Food Safety Initiative [GFSI] and is a member of the Consumer Goods Forum. Though the relationship with GFSI isn't a formal partnership, GFSI is an international organization and has allowed us to play a role in shaping global food safety education."

The GFSI, a non-profit foundation, started in 2000 as an offshoot of the Consumer Goods Forum (CGF), which allows senior managers from retailers, manufacturers and other stakeholders from 70 countries networking and exchange opportunities on non-competitive issues. About 40 to 45 percent of CGF board members are from U.S. companies. The goal of the GFSI is "safe food for consumers everywhere," which it aims to provide by creating independent, scientifically sound food safety benchmarks, and then educating farmers, processors, packagers, retailers and everyone else in the food chain on how to meet and maintain these standards. ››

PHOTO COURTESY OF LES BOURQUIN

MAES food safety scientist Les Bourquin has conducted food safety symposia around the globe and was tapped by leaders of the Global Food Safety Initiative to develop competency-based training modules for manufacturers that would get them to a basic level of food safety. At right, he leads four days of food safety training at the Coca-Cola Food Safety Conference in Shanghai.

As the food supply becomes increasingly global, ensuring that food coming into the United States is grown and processed according to recognized food safety standards is a huge task. The value of foods imported into the United States nearly doubled from 1999 to 2009, rising from more than $41 billion to nearly $77 billion, according to statistics from the U.S. Department of Agriculture (USDA).

"Our curriculum is based on what the international standards say — we work with a lot of international partners to keep the standards global."

Bourquin said that part of the reason that food safety can be such a difficult issue to solve is that food safety standards and their enforcement vary widely from country to country.

"In Europe, for example," he explained, "many of the people auditing food safety are employed by private, third-party companies. In several European countries, the government is less involved in day-to-day inspections, and some accept third-party audits as evidence of compliance. In the United States, the government audits food safety, and the standards are typically uniform for the entire country. Third-party audits also are common in the United States, but the government is primarily responsible for verifying compliance with food safety requirements.

"Third-party auditors are for-profit companies, and each usually has slightly different standards that are followed," Bourquin continued. "It makes it very difficult for farmers, suppliers and processors to keep up and comply with all the different rules."

He related an anecdote about one large multinational firm that analyzed its records and found it was undergoing 40 food safety audits per year, more than three each month. It had a small division full of people who did nothing but troubleshoot the audits.

"For a farmer in a country that lacks enforcement of national food safety standards, such as India, third-party audits are the only verification that safe practices are being followed," Bourquin said. "The farmers have to pay for this themselves, and it's very expensive, so it may not get done."

By benchmarking global standards for food safety, the GFSI aims to cut through the tangle of multiple standards. If a farmer or processor is GFSI-certified against one GFSI-benchmarked standard, that certification is generally accepted everywhere.

To provide the training necessary to help food manufacturers in emerging markets achieve certification, the GFSI tapped Bourquin. Working with colleagues at MSU as well as several international partners, he led the development of competency-based training modules for manufacturers that, once completed, will get them to a basic level of food safety. Called the Food Safety Knowledge Network, the materials are available at www.fskntraining.org/ and www.foodsafetyknowledgenetwork.

org/, though they are undergoing continual refinement.

"We're building competency in the people at companies who oversee food safety," he said. "There are assessment tools built in, so we can monitor what has been learned."

Bourquin and Deepa Thiagarajan, director of global food standards and value chain development programs in the MSU Institute of International Agriculture, piloted the modules in India, and all involved were very pleased with the results. In December 2009, Coca-Cola asked them to conduct an expanded program in Shanghai, China. Though U.S. consumers may associate Coca-Cola with its flagship soft drink, the company distributes hundreds of brands around the world, including fruit juices, sports drinks and teas. Concerned about the food safety practices of some of its Chinese suppliers, Coke awarded a grant to MSU so that Bourquin and Thiagarajan could conduct four days of training for suppliers and manufacturers. The MSU China Office, MSU Global, and MSU Virtual University Design and Technology also collaborated on the project.

"Everyone was very satisfied, very pleased with what they called the Coke Food Safety Conference," Bourquin said. "The content of our course is similar to what's been taught for a number of years. The novelty of our approach is that it's linked to what companies need to accomplish in a very systematic way. We've designed protocols and standards that spell out exactly what manufacturers have to do. Our curriculum is based on what the international standards say — we work with a lot of international partners to keep the standards global. It's not just food safety information in a vacuum."

"Industry asks for the information and we're happy to provide it. We give them the principles based on our research."

The United Nations Industrial Development Organization, another project collaborator, was so impressed with the modules that it translated them into Arabic and used them for training in Egypt.

When he's not conducting seminars, Bourquin is developing modules for the intermediate level food safety standards, as well as standards for fruit and vegetable production.

"Everyone involved wants to continue," he said. "We're also working with Dan Clay and MSU Global on a project funded by the World Trade Organization to conduct economic development in Thailand and Vietnam that's tied to further development of the modules. The goal is to help those countries build trade capacity for fresh and processed fruit and vegetable products."

The Asia-Pacific Economic Cooperation (APEC) Forum also has taken note of Bourquin's work. The organization convened an expert group on food safety training in Washington, D.C., and said that what Bourquin is doing with GFSI is exactly what it wanted to do. In November, the APEC is planning an event in Beijing and has asked Bourquin and Thiagarajan to participate.

"This is exciting because it's all public sector," he said. "The Coke event was private. The event in Beijing will allow us to reach a different audience. It's going to focus on basic food safety requirements generally applied to the food industry and emphasize good practices for aquaculture."

Closer to home, in Battle Creek, Bourquin is on the advisory council of the International Food Protection Training Institute (IFPTI) and has helped develop curriculum for it. The non-profit institute was created through a grant from the W.K. Kellogg Foundation to provide systematic continuing education and training to state and local food inspectors, a void that officials from the Michigan Department of Agriculture and professional organizations pushed to have filled.

The U.S. Food and Drug Administration and USDA do some of this training, including courses now conducted in partnership with

MAES food engineer Kirk Dolan spends a good part of his time conducting training seminars and courses on thermal processing.

Maria Lapinski, MAES health and risk communication scientist, is part of a team studying food handling practices at a group of daycare centers. The goal is to find out where contamination could happen and develop materials to help workers avoid it.

the institute, but don't have the resources to keep up with demand. The IFPTI offers baseline training in a number of areas as well as leadership courses. Its aim is to provide professional development for general food inspectors. Some courses have been taught at MSU to take advantage of specialized facilities, such as the MSU Dairy Plant.

"MSU has a long history of food safety research, outreach and education," Bourquin said. "It predates me. I'm part of the continuum."

Thermal Training

In addition to his research to develop models for food companies that use thermal processing *(see story page 10)*, MAES food engineer Kirk Dolan spends a significant portion of his time conducting training seminars and courses. He's taught at the IFPTI and is part of an annual food safety seminar sponsored by the Institute of International Agriculture. He also runs a yearly process control school and regularly teaches classes on HACCP and aseptic systems for USDA inspectors and private companies. Nestlé-Gerber saw so much value in his process control school that it invited him to teach it in Poland.

"I'm involved in training programs throughout the year," Dolan said. "Industry asks for the information and we're happy to provide it. Post, for example, wanted a short course on food science for non-food-science people. So I taught a class every Wednesday for six weeks for Post employees. We give them the principles based on our research, and then the manufacturers tailor it to their specific operations — we show them how to implement the information."

Dolan maintains close contacts with industry, and these connections have helped him create new twists on standard training and corporate-sponsored research partnerships. The career trajectory of Dharmendra Mishra, one of his graduate students, illustrates Dolan's creative thinking.

After completing his master's degree in food engineering under Dolan's mentorship, Mishra met with representatives from Nestlé-Gerber to discuss internship opportunities. As the internship coordinator for the Food Science and Human Nutrition Department, Dolan brokered the meeting. Impressed with his skills and intelligence, Nestlé-Gerber hired Mishra for a six-month internship. Even more impressed after having him in-house for half a year, Nestlé extended his internship for another five months. When he returned to school to start his doctorate in 2009, the company knew it wanted to keep him. So in January 2010, Mishra was hired full-time as senior associate processing engineer at the company's Fremont facility. After discussing options with Dolan, Nestlé also agreed to pay for Mishra to acquire his doctoral degree. His schedule is flexible

so he can travel to East Lansing for classes and research.

"Mishra showed that he was outstanding, and Nestlé wanted to keep him," Dolan said. "It's a mutually beneficial situation. The research he's doing for his doctorate is directly applicable to the work he's doing in Fremont. In one sense, MSU is educating an employee specifically for Nestlé."

"My expertise is in processing baby food," Mishra said. "I'm studying nutrient breakdown during thermal processing. We want optimal nutrients in the products, but it's a balance between the safety of the food and the quality of the food. Both are very, very important for baby food.

"It's exciting to apply knowledge that I've learned on a daily basis in my job," he continued. "Nestlé is very focused on research, and MSU is well positioned to collaborate with industry. MSU benefits from my work because I'm adding to the body of knowledge on thermal processing. Nestlé benefits because my work can be immediately applied."

Safer Food for Kids

In Michigan, more than 473,000 children younger than 6 need care during the day because their parents work, according to figures from the National Association of Child Care Resource and Referral Agencies. And while they're in daycare, these children need to eat.

To improve food safety and hygiene practices at childcare centers in Michigan, Maria Lapinski, MAES health and risk communication scientist and associate dean for research in the College of Communication Arts and Sciences, is part of a team studying food handling practices at a group of daycare centers to identify where contamination could happen and then develop training materials to help childcare workers avoid it.

The research is funded by a USDA National Integrated Food Safety Initiative grant. MSU scientist Ewen Todd leads the project, which also includes researchers from New Mexico State University, Kansas State University and Rensselaer Polytechnic Institute, as well as MSU communications doctoral student Jenn Anderson and communications graduate student Chelsea Fristoe.

The childcare centers are all in the Ann Arbor area, and all are state-accredited commercial facilities — no in-home centers are part of the study.

"We know there is quite a bit of disease transmission at childcare centers, but there's not a lot of information on how that happens," Lapinski said. "Childcare providers play various roles: they change diapers, they wipe noses, they prepare food. There are both economic and public health consequences of illness in childcare centers. The economic impact of illness at a childcare center affects both center employees and parents — neither can work."

The three-phase project mainly focused on bacterial and viral contamination because those pathogens are believed to be the most common in childcare centers. In phase one, the researchers took microbial swabs at the centers — no dangerous levels were found — and interviewed center workers and directors. They also observed workers, watching how often they washed their hands and looking for opportunities for more hand washing.

"We know there is quite a bit of disease transmission at childcare centers, but there's not a lot of information on how that happens."

"Because the centers are licensed by the state, which is very supportive of the project, workers have to wash their hands at certain times, such as after changing diapers," Lapinski said. "We looked at the frequency and quality of the hand washing to see if improvements could be made."

Having observers in the room might cause care providers to subconsciously improve their hygiene practices, but Lapinski said the scientists took steps to avoid any behavior bias. No one knew why the observers were stationed in the classrooms; because the centers are in a university town, various researchers are often in and out, so having strangers sit in for a week or two wasn't that unusual.

In phase two, which is just wrapping up, the scientists are using the information they collected in phase one to create a risk assessment model that will identify behaviors that could be changed to reduce the risk of disease transmission. The final phase will develop the messages and training materials to change the behavior of the childcare providers and evaluate the success of the materials. Lapinski said the training materials should be done by the end of the year, and the evaluation will be done by an independent authority next year.

"We want to determine the best intervention points," Lapinski explained. "For example, placement of sinks can affect how well and how often people wash their hands. But that's not something we can influence with training — we can make recommendations about things like that, though.

"The reality is that childcare providers do an amazing amount of work to keep kids safe," she continued. "We don't want to add a burden, but if there are places to intervene to make things safer, it makes sense to do that."

— Jamie DePolo

A VIRTUAL SUCCESS

ONLINE MASTER'S PROGRAM PROVIDES GREATER FLEXIBILITY, ADVANCED FOOD SAFETY EDUCATION TO WORKING PROFESSIONALS

"My work schedule is kind of rigid and it's kind of crazy at home with the farm and all the responsibilities that are part of my life and my community. I realized that the online professional master of science in food safety program would allow me to take courses at my own pace and that I could take them in my kitchen — or at Starbucks."

"The professors are people with actual real-world knowledge, not textbook ideals that don't connect to the actuality of the situation and challenges faced in food safety."

"The flexibility of the program and the scope of the courses allowed me to push my limits of creativity while broadening my knowledge of food safety and provided a sound academic background for the work I do day-to-day."

"I was just notified that I was selected for promotion to chief warrant officer III. I am sure my degree placed me well above my peers in the selection process."

"The difference with an online program is that you are always 'on time.'"

These are just a few of the many positive comments received from students and alumni of the nation's first and only fully online Professional Science Master's (PSM) in Food Safety Program, offered through the MSU College of Veterinary Medicine. The program — which received a 98 percent overall satisfaction rating in a 2009 program assessment sent to current students and alumni — allows students to complete their master's degrees from home, work or the road as personal and professional needs dictate.

"This innovative graduate degree program is designed to help food safety professionals pursue advanced training in food safety while simultaneously developing workplace skills highly valued by employers," said Julie Funk, associate professor of large animal clinical sciences and director of the

Graduate student Chau Nguyen demonstrates the accessibility of the online master's program in food safety.

"The capacity to innovate depends not only on scientific discovery, but also on the ability to translate new knowledge into products and services."

— from "Professional Master's Science Programs Merit Wider Support," Science Magazine, March 27, 2009

program. "Students learn how to evaluate new technologies as they arise; address new concerns related to food security, emerging food-borne pathogens, zoonotic [transmitted from animal to human] disease or biotechnology; and develop the organizational and leadership skills that will allow them to be more effective, efficient and confident in an ever-changing workplace."

Although it may seem strange to some that a food safety program would be offered through a veterinary medical college, Funk said that it's a natural place for the program to be housed.

"Veterinarians have always played a key role at the preharvest level on the farm, making sure that animals are wholesome, disease-free and ready to go to market," said Funk, who was a veterinarian in swine practice before heading up the PSM food safety program. "Veterinarians also serve as the principal inspectors for all meat products leaving USDA-inspected plants. They have historically served as public health officers and have been charged with many of the food safety responsibilities for the armed services, making sure that food for the troops is safe. They are integral players in the food safety equation."

A Higher Degree of Food Safety Education

The impetus for the PSM food safety program, now in its eighth year, was the findings of a market survey commissioned in 2000 by the late Ed Mather, former professor and deputy director of the National Food Safety and Toxicology Center at MSU.

"As the food system was becoming more globalized and the challenges of maintaining a safe and secure food supply more complex, there was recognition by Mather, other MSU faculty members, and key government and food industry stakeholders of the need for advanced food safety education," Funk explained. "However, it was really unclear who the best target audience was or how to go about setting up a program — would the need be best addressed by short courses and executive training or an outreach-type program, or was there really a need for a formal degree program?"

Mather asked MSU communications colleague Janet Lillie (who is now associate dean for undergraduate education in the College of Communication Arts and Sciences) to develop a strategy to assess interest in and the best venue for advanced food safety instruction. Lillie conducted phone interviews with employers and students from across the country that might be interested in an advanced food safety program to get a read on their education needs and expectations. Survey findings revealed that the greatest need for food safety education was for people already working in the field.

"Respondents indicated that they would love to get an advanced degree — a master's degree — but the problem was that they couldn't just pick up their families, stop work and come back to MSU for a traditional degree," Funk said. "Nor were the skills that they wanted necessarily the ones acquired in a traditional master's program — a thesis-based degree that is research-intensive and research career-path-focused."

At the same time the survey was being conducted, Funk said that online education was beginning to emerge as a viable possibility.

"It's hard to overstate the importance of being able to offer this degree online," she said. "People need the flexibility. There's always new knowledge coming out. An online program allows you to put quality, scientific education at students' fingertips wherever they are, at any time, and allows people all over the world to interact in the same place."

Funk added that universities were also beginning to experiment with the idea of professional master's programs that develop advanced scientific knowledge and skills such as communication, risk analysis and crisis management.

"There's a critical need for people with advanced degrees in applied sciences," she said, "and they need some complementary skills to go along with their science knowledge, skills that will allow them to be successful in the workplace, whether it be an industry, government or nonprofit organization position.

"The coming together of the need for food safety education beyond the classroom, the emergence of online education and the idea of a professional science master's compelled Mather to develop and launch the program in 2002."

Since then, the program has seen its enrollment grow from a handful of students to 70 alumni and 120 current students. Collectively, they represent 33 states and 13 countries.

It Takes a Village...to Ensure Safe Food

Funk was quick to add that, although the PSM food safety program is offered through the veterinary college, it is an interdisciplinary curriculum.

"We have staff and faculty representation from colleges and departments all across campus, including agriculture and natural resources, animal science, business/hospitality, food safety and toxicology, food science and human nutrition, packaging and – of course— veterinary medicine," she said. "We even work with the School of Criminal Justice to provide instruction on the risk of intentional threats from food-borne terrorism."

MAES large animal clinical scientist Dan Grooms has been involved with the program as an instructor since its inception and worked with Mather in conceptualizing the program. He currently teaches a one-week food protection and defense class, and he organizes a four-module preharvest food safety course. Grooms' teaching approach illustrates the interdisciplinary makeup of the program's curriculum.

"What I've elected to do is reach out to my colleagues around the country and at MSU and ask them to participate," Grooms said. "We have researchers from Mississippi State University, the University of Nebraska, Western College of Health Sciences in California, as well as MSU faculty members and folks in private industry that teach and help with the course development for preharvest food safety. It's a team-taught course — we've got a lawyer, microbiologists, a poultry veterinarian, epidemiologists — the teaching cuts across many areas."

Funk added that Mather preferred to use the term "transdisciplinary" in describing the program because its focus on food safety, both within and beyond discipline boundaries, presents the possibility of new perspectives that can be used to address contemporary issues that cannot be solved by one or even a few points of view.

"Einstein said, 'You cannot solve a problem at the same level of thinking that created it.' This program provides an incredibly rich learning environment because the students are working professionals, so they bring real-world problems to the courses," Funk said. "I think that feeds faculty knowledge about what the challenges are in the food safety field and informs their research direction and priorities. The students, in turn, have a direct link with the people doing the research and access to an international community of practitioners with whom they can network. It's a win-win scenario – each group informs the other for the benefit of all."

Where Science and the Real World Meet

Perhaps one of the most innovative aspects of the PSM food safety program is the application model upon which it is based.

"The idea of a professional science master's that allows people to apply science in their workplaces is becoming increasingly relevant," Funk said. "The PSM food safety program is heavily targeted toward application and culminates with an applied project rather than a more traditional thesis."

Students are required to complete a three-credit food safety applied project before graduation from the program. To emphasize the importance of these projects, an outstanding student award was established in 2007. The award is given annually to recognize students whose projects make significant contributions to the food safety field.

The program's first outstanding student award was given to Marianne Courey, a Michigan Department of Agriculture food inspector, for her work on food safety risks during transportation.

"Marianne was concerned that food wasn't being transported under the right temperatures or with the right protection," Funk said. "So, to begin her project, she developed an educational CD for people who transport food. That evolved into a multistate, multiorganizational, real-life road survey, where trucks were being pulled off the road and checked to see if they were hauling food and, if so, if they were hauling it under the appropriate conditions."

Frank McLaughlin, chief warrant officer III in the U.S. Army Veterinary Corps, received the award in 2008 for conducting survey work that examined the relative food safety and food protection levels of European food suppliers to Army personnel in those regions.

"Frank really focused on international threats, and that led him to a job where he is helping to write policy around food

Julie Funk, associate professor of large animal clinical sciences and director of the program, interacts online with students

protection defense," Funk said. "He is also providing instruction to future veterinary corps food inspectors."

Heather Farrell Clark, quality assurance manager, Barbados Dairy Industries, Ltd., was the 2009 award recipient.

"A lot of the Caribbean countries are beginning to explore the need for their own equivalent of a national food safety organization," Funk explained. "Heather conducted a needs assessment to get feedback from government officials and food producers in Barbados about the efficacy of a national food safety organization there. Assessment findings showed the need and support for such a group."

This year's winners, Susan Linn, director of quality assurance, SYSCO Corporation, and Angie Lawless, director of crisis management for RQA, Inc., teamed up to examine the food recall process.

"Susan and Angie surveyed people who work in the food supply chain to gain a better understanding of what works and doesn't work for them in food recalls, how they prefer to receive information, and what their food recall capabilities are," Funk said. "Based on the findings, RQA and SYSCO improved their recall systems to help make recalls more efficient and protective of people.

"We've had everything from bench-top molecular work to children's books come from these initiatives," Funk added. "The program is very broad in the types of projects students can pursue because, to solve food safety problems, it takes people from many disciplines taking many approaches. Again, the program is real-world-focused — if students can actually apply it at their place of work, we're having an impact."

Advancing Food Safety: Where the Rubber Meets the Road

In addition to providing essential scientific knowledge, complementary workplace skills and an opportunity for students to apply what they've learned though an applied project specific to their interests or line of work, Funk said that program staff and faculty members hope the PSM food safety program can provide a number of other benefits.

"One of the other things we hope to achieve is improved communication across sectors, whether it be government to

Profile: Online Professional Science Master's Degree in Food Safety Program

The online Professional Science Master's (PSM) in Food Safety Program, offered through the MSU College of Veterinary Medicine, is the nation's first and only fully online food safety program and the only online PSM program housed in a veterinary medical college. It is part of a national network of 208 PSM programs that are offered through 98 affiliated institutions across the country. All of the information provided below is current as of Sept. 1, 2010.

Program started:	**2002**
Current enrollment:	**120 students**
Number of graduates:	**70**
Credit requirements:	**30 (21 core course credits, including a three-credit applied food safety project, and nine elective credits)**
Residency requirements:	**None**
Time limit:	**Five calendar years (the last 30 graduates took an average of 2.7 years to complete the program)**
Number of faculty members:	**29**
Core courses:	**Introduction to food safety, evolution and ecology of food safety, food safety toxicology, food safety research methods, food-borne disease epidemiology, food safety epidemiology, U.S. food laws and regulations, international food laws and regulations, and applied food safety**
Elective courses:	**Special studies in food safety, packaging for food safety, preharvest food safety, food protection and defense, topics in food safety, food safety disease control, product protection/anti-counterfeit strategy, food law, homeland security and public health**
Sectors represented by students:	**Industry (74 percent), government (17 percent) and academia (9 percent)**
Geographic representation of students:	**33 states and 13 countries**

For more information: www.online.foodsafety.msu.edu.

Note: A 12-credit certificate in food safety is also available. Seven food safety certificates have been awarded to date.

industry or across different parts of the food supply chain," Funk said. "We also hope to create a community of scholars who will, in the future, set food safety policy."

Funk added that a good number of the students have told her and other program staff and faculty members that a week rarely goes by in which they don't contact a colleague.

"They rely on each other a lot, even after graduation, for their respective expertise on food safety issues," she said. "If they run across something that they need assistance with, they can say, 'Oh, so and so knows about this, so I can call him/her.'"

"In today's world, developing diverse networks of colleagues is necessary to solve complex problems," Grooms added. "There is no doubt that food safety is a complex issue. This program not only enhances knowledge but also builds this diverse network, thus further helping to ensure food safety globally."

Funk is enthusiastic about the future of the program and its ability to provide access to an advanced food safety degree that, for many, would otherwise be difficult — if not impossible — to attain.

"This degree is not designed to replace traditional programs but to help working professionals gain the advanced instruction and skills training they need to be successful," Funk said. "We're trying to create a broad network of professionals that are equipped to address the food safety challenges of the 21st century. We're committed to a safe food supply."

— *Val Osowski*

Research *in the news*

Research May Lead to New Lung Cancer Treatments

An MAES researcher is analyzing the immune system's ability to protect the body against lung cancer.

The results of work by Alison Bauer, MAES pathobiology and diagnostic investigation scientist, are expected to provide new approaches to prevent, identify and treat lung cancer. The disease is the leading cause of cancer-related death in Michigan and the country.

"Chronic inflammatory lung diseases such as asthma and chronic obstructive pulmonary disease are risk factors in the development of lung cancer," Bauer explained. "However, activation of certain components of the immune system — namely the part of our immune system that responds first to an injury, or the innate immune system — may provide protection against lung cancer development."

Previous research has determined that farm and textile workers exposed to elevated levels of a bacterial component called endotoxin are at a reduced risk of developing lung cancer, Bauer explained. After being introduced to the body, endotoxin binds to a specific protein on cells known as "toll-like" receptors; these receptors are involved in innate immunity. The primary receptor binding endotoxin is called toll-like receptor 4 (TLR4).

Bauer and her team have previously shown that TLR4 acts in a protective manner against the development of chronic lung inflammation and lung cancer in mice. That research was published last year in the journal Molecular Cancer. This project will further investigate how and why TLR4 acts in a protective manner, focusing on the cells involved in the inflammation process in mice models.

Bauer also will look at intercellular communication and growth factor regulation. The team will investigate the role of these pathways in TLR4's protective effects. In other cancers TLR4 is required for some chemotherapy drugs to be effective.

This research is funded by a $720,000 grant from the American Cancer Society.

Most Panda Habitat is Outside Nature Reserves, According to Joint MSU-Chinese Research

Though much effort and many resources have been expended to protect the endangered giant panda, research by an international team of scientists shows that much suitable panda habitat is outside the nature reserves and areas where the panda is reported to live.

"This research can help the Chinese government and international non-governmental organizations develop comprehensive strategic plans for more effective conservation of the panda," said Jianguo "Jack" Liu, university distinguished professor and MAES fisheries and wildlife scientist, who holds the Rachel Carson Chair in Sustainability and serves as director of the MSU Center for Systems Integration and Sustainability (CSIS). Liu is internationally known for his work on environmental sustainability and coupled human and natural systems.

"Overall, about 40 percent of the suitable habitat for pandas is inside the nature reserves," said Andrés Viña, CSIS specialist. "Our model also identified potentially suitable habitat outside the currently accepted geographic range of the panda."

The research is published in the journal Biological Conservation.

The giant panda is the rarest member of the bear family. Panda once ranged throughout most of China, northern Vietnam and northern Myanmar. Today, fewer than 1,600 giant pandas live in the wild in three Chinese provinces: Gansu, Shaanxi and Sichuan. Human actions — including logging, residential development and the expansion of farming — are considered the main reasons for the dramatic contraction of the giant panda's habitat.

The research team developed habitat models using geographical/environmental information gathered by satellites overlaid with information on panda occurrence. After analyzing the six mountain regions in the three provinces where pandas are known to live, the scientists developed a habitat suitability index for the entire 48,328-square-mile area.

The range-wide habitat analysis model gives governments and other agencies a new tool as they develop conservation strategies and priorities not only for pandas but also for many other endangered species.

"The Chinese government plans to add approximately 69,500 square miles of land to the country's nature reserve system between 2010 and 2020," said Zhiyun Ouyang, director of the Lab of Urban and Regional Ecology at the Chinese Academy of Sciences in Beijing. "So opportunities exist to create new reserves, to expand existing reserves and to create corridors that increase the connectivity among the reserves. On the basis of our results, we suggest some new areas to be included in China's nature reserve system."

The research is supported by the Michigan Agricultural Experiment Station, the National Science Foundation, NASA and the National Natural Science Foundation of China.

Besides Liu, Viña and Ouyang, other members of the research team are Mao-Ning Tuanmu, MSU fisheries and wildlife doctoral student; Yu Li, MSU fisheries and wildlife master's student; Weihua Xu, professor at the Chinese Academy of Sciences; and Ruth DeFries, Denning Professor of Sustainable Development at Columbia University.

Pest-resistant Soybeans Grow Out of MAES Lab

Two lines of pest-resistant soybean painstakingly developed by an MAES scientist promise healthier harvests for growers and a little green for the university, too.

"Sparta — the Soybean Aphid Shield" is

the new trade name for genetics developed by Dechun Wang, MAES soybean breeder and crop and soil sciences researcher. He tested approximately 2,000 strains of soybeans for their ability to withstand aphids and isolated four with different resistant genes. From those he developed germ plasm and bred varieties suited to Michigan's short growing season.

"The final goal," Wang said, "would be to have one variety that has all those resistant genes," maximizing protection against various biotypes of aphids and perhaps other pests such as Japanese beetle.

Soybean aphids suck plant sap and secrete a sticky substance that promotes growth of sooty black mold. After they sprout wings, the aphids can speed the transmission of plant viruses. Fifteen generations of aphids can live on a soybean plant in the summer; the eggs overwinter on nearby buckthorn.

"In the field, we will inoculate a plant with just two aphids, and the entire plant will be totally covered by aphids in a few weeks," Wang said. "It takes aphids just five days to produce more babies — aphids are born pregnant, so the regeneration cycle is incredibly fast."

Soybeans have been cultivated in Asia for thousands of years but only since 1904 in the United States, where they're mainly processed into animal feed and vegetable oil. Tiny soybean aphids, also native to Asia, were first identified in Wisconsin in 2000 and quickly spread to most soybean-growing areas until mostly controlled with chemical pesticides. Unchecked, aphids can reduce yield by 50 percent, but one pesticide application can increase production costs by 10 percent and also kill beneficial insects.

"Pesticides have really been our only answer until this new host plant material," said Keith Reinholt, field operations director for the Michigan Soybean Promotion Committee (MSPC). His group has funded Wang's research since 2002 with about $250,000 per year from grower assessment revenue, earning it first claim on licensing rights after MSU patented the resistance technology.

The germ plasm is generating interest among seed companies, which will use it to improve their varieties. The MSPC grower board will earn royalties from the sale of seed company varieties containing the trait. A portion of those will come back to MSU, which will in turn distribute royalties to Wang, the College of Agriculture and Natural Resources and the MSU Foundation.

"With one exception, all the major soybean genetics companies have licensed his germ plasm because the level of resistance to soybean aphids is very high," said James Kells, chairperson of the Department of Crop and Soil Sciences. "We're very excited about this technology, and we see great potential for commercialization and impact on soybean growers in Michigan and elsewhere in the United States."

Wang's research also is supported by the Michigan Agricultural Experiment Station.

Researchers Discover Mechanism Protecting Plants Against Freezing

New ground broken by an MAES researcher helps explain how plants protect themselves from freezing temperatures and could lead to discoveries related to plant tolerance of drought and other extreme conditions.

"This brings together two classic problems in plant biology," said Christoph Benning, MAES biochemistry and molecular biology scientist. "One is that plants protect themselves against freezing; scientists long thought it had something to do with cell membranes but didn't know exactly how. The other is the search for the gene for an enigmatic enzyme of plant lipid metabolism in the chloroplasts, shedding light on how cell membrane building blocks are made."

In an article published online by the journal Science, Benning and then-doctoral degree candidate Eric Moellering and technical assistant Bagyalakshmi Muthan describe how a particular gene in *Arabidopsis thaliana*, common mustard weed, leads to the formation of a lipid that protects chloroplasts and plant cell membranes from freeze damage by a novel mechanism.

Working on his dissertation project under Benning, Moellering identified a mutant strain of *Arabidopsis* that can't manufacture the lipid and linked this biochemical defect to work done by others who originally described the role of the gene in freeze tolerance but did not find the mechanism.

"One of the big problems in freezing tolerance or general stress in plants is that some species are better at surviving stress than others," Moellering said. "We are only beginning to understand the mechanisms that allow some plants to survive while others are sensitive."

There is no single mechanism involved in plant freezing tolerance, Moellering added, so he can't say that his findings will lead anytime soon to genetic breakthroughs making citrus or other freezing-intolerant plants able to thrive in northern climates. But it does add to the understanding of how plants survive temperature extremes.

Much plant damage in freezing temperatures is due to cell dehydration — water is drawn out as it crystallizes, and the organelle or cell membrane shrivels as liquid volume drops. Lipids in the membranes of tolerant plants are removed and converted to oil that accumulates in droplets, the researchers said, retaining membrane integrity, keeping membranes from fusing with one another and conserving the energy by storing oil droplets. With rising concern globally about water supplies and climate change, scientists see additional reasons to understand the ways hardy plants survive.

The research, funded by the U.S. Department of Energy Office of Science-Basic Energy Sciences and the Michigan Agricultural Experiment Station, also leads to speculation

that freezing itself can prompt cell proteins directly to change the composition of the membrane, without activation by gradual acclimation. That has been a major focus in the plant freezing tolerance field, the researchers said.

"This opens a huge door now for people to do this kind of research and to redirect researchers," Benning said. "There are lots of them out there trying to understand cold, salt and drought tolerance in plants, and we've given them a new idea about how they can approach this problem mechanistically."

Waste-to-Energy Research and Teaching Facility Opens

Michigan State's new Anaerobic Digester Research and Education Center (ADREC) will advance the science and technology of anaerobic digestion through cutting-edge research and will play a key role in expanding Michigan's bioeconomy.

The facility opened during Ag Expo in July.

"Anaerobic digestion has proven to be a feasible technology to convert waste to resource while minimizing negative impact on the environment," said Ajit Srivastava, chairperson of the Department of Biosystems and Agricultural Engineering. "However, because of the high cost, it's affordable only for large dairy operations. The goal of the ADREC is to develop off-the-shelf anaerobic digestion technology so it becomes cost-effective for small to medium-sized farms [defined as 200 to 499 milking cows]. There are more than 6,000 dairy farms in Michigan that fall in this range, so the potential of AD technology to convert animal manure to energy, all the while reducing greenhouse gas emissions, is huge."

The facility also brings MSU's research resources together under one roof.

"This facility brought together resources that we had spread across four laboratories on campus," said Dana Kirk, visiting biosystems and agricultural engineering specialist, who will manage ADREC. "By building this facility, we're able to bring researchers, graduate students, undergraduates and staff members together under one roof so we can share instrumentation and collaborate."

Anaerobic digesters store livestock waste in a tank deprived of oxygen. The lack of oxygen allows the waste materials to decompose quickly and produces methane that can be captured and used as fuel. When waste decomposes in open tanks, the methane released is an extremely potent greenhouse gas.

"We think MSU can play a very critical role in this industry as it evolves in this country because of the resources we have — both in the faculty and staff members and now in the laboratory facilities," said Steve Safferman, MAES biosystems and agricultural engineering scientist.

The U.S. Environmental Protection Agency and U.S. Department of Agriculture recently announced a new interagency agreement promoting renewable energy generation and slashing greenhouse gas emissions from livestock operations. The collaboration provides $3.9 million over the next five years, expands technical assistance, improves standards and guidance, and expands outreach to livestock producers.

The EPA estimates that 150 on-farm manure digesters are operating across the country and that about 8,000 farms are good candidates for capturing and using biogas.

If all 8,000 farms implemented biogas systems, methane emissions would be reduced by more than 34 million metric tons of carbon dioxide equivalent per year, which is roughly equal to the annual emissions from 6.5 million passenger vehicles. In addition, these projects could generate more than 1,500 megawatts of renewable energy.

"The methane gas can be used instead of conventional energy sources," Kirk said. "It can directly replace natural gas if we scrub out the impurities — it actually can be inserted in the pipeline and burned in a home. Methane gas typically has been converted into electricity by using it as the fuel source for a turbine or an internal combustion engine."

"Instead of waste being an environmental burden on the environment, it's now an asset and a very much needed commodity," Safferman added.

Insecticides Can Affect Wild Bee Populations, MAES Research Shows

Fruit and vegetable growers all over the country rely on pollinators — mainly bees — to produce crops from blueberries to almonds. In addition to managed honey bees, wild bees that live in and around crop fields also provide pollination services.

To help growers make pest control choices that conserve these valuable native pollinators, MAES entomologist Rufus Isaacs and entomology postdoctoral scientist Julianna Tuell studied how wild bee populations are affected by pest management programs in highbush blueberries. The research is published in the June issue of the Journal of Economic Entomology.

During crop bloom, growers avoid using insecticides or use only bee-safe products to ensure that pollinators are protected. After bloom, honey bee colonies are removed from the fields, but wild bees stay in the fields.

"A rich wild bee community can be present before, during and after blueberry bloom, with more than 100 species of wild bees found in these fields," Tuell said. "Of these, approximately 10 species are present in high numbers and consistently pollinate blueberries."

"Michigan is the leading producer of blueberries in the world, and this crop is very dependent on pollination for good yields," Isaacs added. "It also faces some important

insect pest challenges. This provides a great opportunity to test the hypothesis that insecticide applications made when the crop is not in bloom affect the wild bee community present during the bloom period — when bees are most important to the crops and to the growers."

Tuell and Isaacs developed a risk index to quantify the relative risk to wild bees from insecticide applications to blueberry fields and then analyzed the relationship between the index and the abundance, diversity and species richness of wild bee communities over three growing seasons. The study also evaluated the stability of the wild bee population.

In the last two years of the study, bee abundance and species richness declined with increasing insecticide risk index values. Bee diversity declined only in the first year.

"The results indicate that wild bee communities are negatively affected by increasingly intensive chemical pest management activities in crop fields," Tuell said.

She said that studying wild bee populations is important because it can help growers make informed decisions about their pest management program that will result in more sustainable crop pollination.

"Most insecticides are applied after the crop is finished blooming," she said. "Growers who rent honey bee hives know to avoid spraying insecticides until after hives are removed. Many native bees live in the ground and nest in crop fields or in field margins, where they are likely to come into contact with postbloom insecticides."

Using the scientists' results, growers can make more informed choices about how to manage pests while continuing to get benefits from wild bees.

"Growers can reduce the toxicity and amount of insecticide they apply for pest control, and they can make adjustments in application timing," Tuell said. "More focused spraying that targets only pest-infested areas also is expected to improve the overall farm environment for bees. Our data suggest that reducing the risk of pest control programs to bees will help conserve populations of these beneficial pollinating insects that are active during crop bloom."

"With fruits and vegetables an increasing component of the nation's diet and honey bee colonies continuing to face challenges, it makes good sense to find strategies to help promote wild bees on farmland," Isaacs said.

Savvy Consumers Put High Price on Food Safety

In recent weeks, news media have covered stories on an Angus beef recall, oil-tainted Gulf shrimp and *Salmonella*-infected eggs.

Anecdotal evidence suggests that such headlines affect consumer spending. New research from Michigan State University demonstrates how these announcements affect how consumers and food industry professionals make purchasing decisions.

Consumers are not only quite attuned to food safety issues — they also have significantly changed their shopping habits because of them, says MAES scientist Chris Peterson, director of the MSU Product Center for Agriculture and Natural Resources.

Similar patterns also are evident among food industry professionals — manufacturers, distributors, retailers — a majority of whom have, in the past five years, changed their business practices in response to concerns about the safety of food products. The Product Center study, "Food Safety Certification: A Study of Food Safety in the U.S. Supply Chain" was sponsored by Oslo-based Det Norske Veritas and conducted via online surveys of more than 400 consumers and nearly 75 food companies. DNV is a global provider of services for managing risk.

Nearly half of the consumers surveyed reported a change in shopping patterns due to food safety concerns. Also noteworthy is that the research subjects indicated that higher price and brand name are not direct signs of safer food, Peterson said.

"Consumers are not only changing their buying habits — they also want to see evidence on product labels indicating that their food has passed some kind of independent safety certification process," he said. "Moreover, slightly more than one-third of consumers are willing to pay a premium — upwards of 30 percent more — for food with a safety certification label."

Food industry professionals also value third-party certification but place a higher value on traceability. Food comes from a complex and interconnected food chain. If there is an outbreak, the immediate industry priority is to trace its origin, Peterson said.

"It's sort of the 9-1-1 mechanism of food safety," he said. "So we are not surprised that industry professionals place more emphasis on traceability, while consumers want to see the certification on product labels. In fact, they still see government inspection as the most credible signal of food safety, with certification and traceability coming in a close second and third."

In addition, the study found that:

- Food suppliers and consumers believe that recycling, social justice, green practices, economic viability and animal welfare are important indicators of sustainability. But the most important attribute is safer and healthier food.
- Consumers have particular concern about domestic meat products and, in general, all products coming from international sources.
- A significant number of food suppliers are moving to implement certification audits primarily as a risk management tool. In general, food suppliers see a need for lower cost of implementation and a more consolidated/harmonized set of standards for third-party food safety certification.

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