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Agricultural Research

The Lab That Keeps the Pickle on Your Plate

Story on pages 4-9

Agricultural Research Service • *Solving Problems for the Growing World*

(D3186-1)

Enhancing Food Safety by Supporting Regulatory Agencies and Industry

For the regulations that govern our food safety to do the best job of protecting us, they need to be rooted in sound science. Providing that science is a basic part of the Agricultural Research Service's mission. But our food producers and processors must also know how to meet those regulations in an efficient, effective manner.

To accomplish this, ARS provides support to other agencies, for example, the U.S. Department of Agriculture's Food Safety and Inspection Service (FSIS) and the U.S. Food and Drug Administration (FDA), and works with industry stakeholders so that they all have the knowledge and tools to supply consumers with safe food.

Regulatory agencies often contact ARS to fill a specific need for data as a regulation is being developed. For example, when FDA began developing its rules for using raw manure as a soil amendment under the Food Safety Modernization Act, it needed solid objective data about how long pathogenic bacteria actually survive in manure-amended soils in different cropping systems and environments. So the agency turned to the ARS Environmental Microbial and Food Safety Laboratory in Beltsville, Maryland, to conduct the needed field studies and analyze the data.

The ARS Food Safety and Intervention Technologies Unit in Wyndmoor, Pennsylvania, working with Drexel University, is providing FSIS and FDA with the most comprehensive survey of the bacterium *Listeria monocytogenes* in retail ready-to-eat foods conducted in the past decade. The bacterium is one of the leading causes of death related to foodborne illness. This long-term study is looking at the distribution, rates, amounts, and subtypes of *L. monocytogenes* in ready-to-eat foods. Such data will allow an assessment of changes in *Listeria* prevalence and levels in these foods and will help validate interventions to ensure a wholesome food supply. Having current information is essential for FSIS and FDA to be able to revisit their *Listeria* Risk Assessment program, evaluate the relative public health risk, and effectively allocate their resources to mitigate that health risk.

At other times, ARS works more directly with industry on how to best to meet regulatory requirements for food safety by developing new knowledge and cost-effective tools to reduce risk of foodborne illnesses.

When concerns were raised about the survivability of pathogens in acidified foods, both FDA and the pickling industry turned to the ARS Food Science Research Unit in Raleigh, North Carolina, to do the research that would ensure consumer safety. This lab has a long history of ensuring food safety in commercial pickling. You can read the details of that story beginning on page 4 of this issue.

Sometimes ARS provides support by developing tools that will help regulatory agencies and industry enhance food safety. One such tool is ARS's Integrated Pathogen Modeling Program (IPMP 2013), developed by the Residue Chemistry and Predictive Microbiology Research Unit in Wyndmoor. The food industry needs mathematical models for predicting microbial growth and survival in foods, and the regulatory agencies need the models for conducting risk assessments of our food supply. However, developing such microbial models is not a trivial task; it commonly requires advanced training in statistics, mathematics, and even computer programming. IPMP 2013 simplifies the problem. It is a fully automated tool that allows accurate models to be developed without any programming knowledge or experience.

ARS offers this software package as a free tool to scientists and risk modelers around the world. Regulatory agencies and industry are already benefitting from it. Universities are also using IPMP 2013 to train the next generation of food safety managers on how to correctly develop models to predict microbial growth and survival in foods.

ARS-funded researchers at Purdue University's Center for Food Safety Engineering in West Lafayette, Indiana, are also helping food safety agencies by reducing the time it takes to identify harmful bacteria in food with the development of BARDOT sensor technology. This easy-to-use, portable system has tremendous potential for improving response to foodborne illness outbreaks, because the testing can be performed at the source, rather than in the laboratory. The utility of the BARDOT system was demonstrated by its ability to detect *Salmonella* in peanut butter within 24 hours with an accuracy of 98 percent, compared to the current FSIS method, which requires about 72 hours.

Whether ARS researchers are working with regulatory agencies, industry, or both, the sound, objective science they are providing is ultimately benefitting the consumer by ensuring that our food stays as safe as possible at every step from the farm to your table.

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Solving Problems for the Growing World

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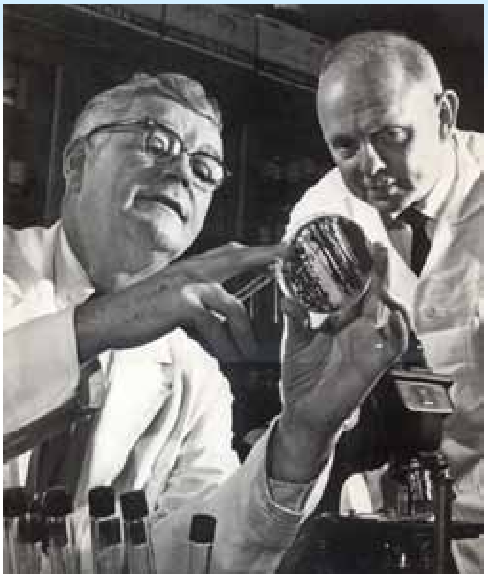
STEPHEN AUSMUS (D1422-13)

When it comes to producing a fish feed ingredient from barley for use in aquaculture, the trick is to make sure the ingredient is high enough in protein to promote fish growth and development. Story begins on page 12.

Cover: Today, dill pickle slices are practically standard on hamburgers in restaurants everywhere, representing 25 percent of the pickle market. The boom in everything from dill slices to sweet relishes on grocery store shelves has its roots in the efforts of one ARS laboratory in Raleigh, North Carolina. Story begins on page 4. Photo by Stephen Ausmus. (D3179-3)

(D3167-1)



A Lab That Keeps Us All Out of a Pickle

MT. OLIVE PICKLE CO. (D3170-1)

Left: John L. Etchells (on the left) led the ARS food science laboratory in Raleigh, North Carolina, from 1937 until 1975. He developed the first commercial pasteurization process for shelf-stable pickles, among many other contributions to pickle safety. Etchells is shown here conferring with Tom Bell, research leader of the lab from 1975 to 1977. Right: Pickled peppers are delicious in sandwiches, salads, and more.

George Washington had a collection of 476 kinds of pickles. To prevent scurvy, Christopher Columbus stocked pickles on the Niña, Pinta, and Santa Maria. Julius Caesar, believing pickles to be invigorating, added them to the Roman legions' diet. In 5000 BCE, the Babylonians were known for pickling with date palm vinegar. Pickling—storing food in a salty brine or an acid solution, usually vinegar (acetic acid)—is one of humankind's oldest ways of preserving foods.

Pickles have always been popular in the United States. Today, they are having a widespread renaissance, powered in part by trendy interest in craft brands that are showing up in local stores and farmers markets all over the country. Today, each American eats an average of 9 pounds of pickles a year.

While pickling was recognized as a safe

JANET KAPLAN (D3184-1)

food-preservation method long before the discovery of bacteria, the kind of data that today's precise food safety standards require was not established until relatively recently.

By the mid-1990s, there had not been a foodborne-illness outbreak traced to commercial pickle production in 50 years, and the basic practices that producers were following had long been considered acceptable. But in the late 1990s, incidents of bacterial contamination in acidic foods like unpasteurized orange juice and apple cider, which are the same pH as pickles, led to some sickness and even deaths. The incidents alerted the U.S. Food and Drug Administration (FDA) that pathogens such as *Salmonella* and *Escherichia coli* O157:H7 survived at more acidic pH levels in juices than previously believed, and this led to new juice regulations. It also raised collateral questions about these pathogens in acidified foods such as pickles. This resulted in closer scrutiny of acidified food processes and prompted FDA to issue draft guidance applicable to the pickle industry.

"In the 1970s, when acidified food regulations were promulgated, the state of the science for microbial hazards in acid and acidified foods was not as well understood as it is today," explains Don Zink, senior science advisor at FDA's Center for Food Safety and Applied Nutrition. "It was time for the regulations and industry guidance to catch up with the science of today."

The concern, unlike in the 1970s when botulism was the primary worry, was making certain that *E. coli* O157:H7, *Salmonella,* and *Listeria* cannot survive the pickle-making process to cause illness. FDA has generally regarded a 99.999 percent, or 5 log, reduction in the bacterial pathogen population (which means cutting the number of bacteria present by 100,000 fold) to be sufficient to lower the public health risk to a negligible level.

Changes in the pickle industry also contributed to the need for better scientific understanding. For example, cold-packed pickles have become popular in recent years, and the processes for making them are very different from those for traditional pickling. But no one knew for certain precisely how long pickled vegetables need to spend at what concentration of acid and at what temperature to achieve the desired 5 log reduction, Zink points out.

Supplying Scientific Precision

That's where the Agricultural Research Service came in. The agency's Food Science Research Unit, in Raleigh, North Carolina, is the only national laboratory that works full time on the processing of commercial pickled vegetables. Areas of research include food safety, microbiology, chemistry, food technology, and methodology.

With significant support and funding from the pickle industry, unit microbiologist Frederick Breidt and his team investigated how to consistently reach the 5 log reduction requirement and how to do it without harming the quality of the pickle products.

"The first ones we worked on were the simplest: the pasteurized pickles—dill, bread and butter, sweet, sour, gherkin, kosher—the ones that pretty much dominate the grocery store aisles," explains Breidt. "What we found was that it took less than

Opposite page: Pickles are showing renewed popularity in the United States partly because of growing interest in craft brands sold in farmers markets. Below: Pickled vegetables and relishes fill several grocery store shelves. Each American eats about 9 pounds of pickles a year.

STEPHEN AUSMUS (D3180-2)

SANDRA PARKER (D3181-2)

ARS microbiologist Frederick Breidt developed the specific data needed for each type of pickle so that pickle manufacturers could prove they are meeting today's exacting food safety guidelines.

1.2 minutes at 160˚F (71˚C) in a brine at pH 4.1 to get a 5 log reduction."

Commercial pickle producers were already exceeding this, using 165˚F (74˚C) for 15 minutes as a standard for pasteurization, to inactivate enzymes and microbes that could harm product quality or cause spoilage.

"But now there is peer-reviewed, published science that proves, rather than assumes, that the industry meets FDA's 5 log food safety standard," Breidt says.

Then Breidt moved on to the acidified, shelf-stable, pickled vegetables, like peppers and okra, which do not undergo pasteurization because they would fall apart in the heat. These products are instead made safe through the combined bacteria-killing effects of low pH and high organic acid concentration, factors that are independent but related.

While the twin bactericidal effects had been previously known, no one had been sure which was more important to food safety or how to separate the impacts. Breidt started unraveling the science of how the pickling process provides food safety.

"We began to investigate what it was in the pickling process—the acid itself or the low pH—that kills *E. coli* more effectively," Breidt says. "In our experiments with fermented products, we found that pH was more significant than acid concentration in affecting *E. coli* survival."

Acid also kills bacteria more effectively at higher temperatures. What Breidt found was that at 50˚F, pickled vegetables in jars need to be held for at least 6 days in vinegar at a pH of 3.3 or below to reach the 5 log reduction. But at 77˚F, the jars only need to be held for 2 days at the same pH. Pickle products that are classified as "refrigerated style" need to be kept below 50˚F. They are governed by a different class of regulations, so time and temperature data was not needed for them.

One thing that surprised Breidt was that certain strains of *E. coli* are the toughest of the foodborne pathogens for most acidified products. "I thought we would have to be most on the watch for *Salmonella* survival. But we found that *E. coli* can survive harsher acid conditions for longer, so we always used *E. coli* strains in our testing."

Finally, there were the iconic sliced dill chips for hamburgers, which come in institutional-sized containers. These pickles are fermented rather than pasteurized, mainly because those containers would hold too much heat, and the pickles would "cook" beyond acceptability. However, Breidt found that the fermentation process itself is sufficient to ensure food safety.

Applying the Lab Work

Zink, who has been involved in both the introduction of FDA's new 5 log reduction requirement and formulating guidance for how to implement it, extolls all the "extra" steps Breidt has taken, saying, "That's what is so important about what Breidt and this lab do. Both FDA and industry can depend on the objective data, the basic science, and his depth of knowledge and expertise so that both sides understand how to reach the goal of great pickles with great assurance of food safety.

"There are not many instances where we have scientists working that closely with both industry and regulators. It's a very good model that promotes a level of cooperation that I wish we would see more often," he adds.

Brian Bursiek, executive vice president of Pickle Packers International, the principal industry association, echoes Zink's praise for the ARS Food Science Research Unit. "Because the staff in Raleigh are intimately familiar with pickling production processes and FDA requirements and procedures, they can help clarify what changes actually mean and require," Bursiek says. "They are helpful in educating industry about how to comply. The lab provided science-based solutions when the industry and FDA needed them."

The respect that the lab's work engenders also supports FDA in other crucial ways. For example, having Breidt's precise data on what conditions achieve a 5 log reduction, an FDA inspector at the U.S. border was well armed while checking a large, very expensive shipment of olives coming from Italy. The inspector found the pH of the solution that bathed the olives to be much higher than what Breidt had reported as effectively safe.

"Given the six-figure value of that shipment, we actually called Fred to double check that the pH was out of the safe range, and then we rejected it for import," Zink says. "Because of this lab's work, there was definitive, objective science on which we based our decision. The import company didn't even go to court to try and fight the

STEPHEN AUSMUS (D3179-5)

After ARS's pickle pasteurization work helped reduce spoilage in the industry, pickles became less expensive, and dill pickle slices became popular on burgers in restaurants everywhere.

FDA ruling in the face of such respected science."

That wasn't the first time the ARS Food Science Research Unit's work has been of specific use to FDA, according to Zink. "Once in a while, when state or FDA inspectors see a pickle production operation for the first time, they are surprised to see large, 10,000-gallon vats open to the sky. They get a little excited and want lids added or suggest that the vats should be made of stainless steel," he recounts. "I always pull out an old journal paper proving that it is the ultraviolet light from the sun that is the sanitizing agent for those vats of cucumbers, that the sunlight prevents mold growth, so they need to be open to the sky and sun. The author of that paper was John L. Etchells, the first research leader of the ARS lab."

That work is just part of a long history of contributions from the ARS Food Science Research Unit.

A Lab With History

Etchells, who led the lab from 1937, shortly after it was formally organized, until he retired in 1975, made many contributions to the science of safe and efficient commercial pickling. But perhaps his greatest contribution was developing the first commercial pasteurization process for grocery store shelf-stable pickles. He also improved the fermentation process and reduced spoilage by a significant amount, which helped make pickles less expensive and increased their consumption in the United States. For example, dill pickle slices became a standard accompaniment on hamburgers in restaurants everywhere, and today, they represent 25 percent of the pickle market.

So highly regarded have his processes been for providing food safety that, in the mid-1990s, they got a pickle supplier off the hook for a food recall when a fast-food chain tried to blame the hamburger pickle as a source of staphylococcal enterotoxin, which would have required a large-scale product recall. The ARS lab tested the supplier's pickle slices for FDA and found that they were indeed clean. Other studies by the lab showed that the positive enterotoxin test was a false positive, caused by natural peroxidase enzymes that formed during the fermentation process. This was accepted as confirmation that the pickles did not contain any enterotoxin.

Etchells also worked out the first preservation prediction chart in the 1950s for sweet pickles that were not pasteurized by heat. It gave an acid/sugar/salt combination for commercial production, ensuring pickles that would be stable during shelf storage.

"This chart is still used as an industry standard," says Carl Gilbert, product planning and scheduling manager for B&G Foods, North America, Inc., in Hurlock, Maryland. "It is still our benchmark. For example, when we are developing a new relish product that is going to be made from fermented pickled vegetables and not thermal-processed (pasteurized), we go back to that chart to be sure we are on the correct side of food safety. If we didn't follow this chart and then had to do a full pasteurization, it would really affect the flavor and texture of the product."

MT. OLIVE PICKLE CO. (D3182-1)

Even at the country's biggest independent pickle producer, Mt. Olive Pickle Company, some products are still packed by hand, but food safety always comes first.

ROBERT FLYNN (K2213-6)

In 1986, ARS's Henry Fleming (right), best known for helping find the cause of "bloating" during cucumber fermentation, walks among wooden open-top tanks used by the pickle industry with North Carolina State University professor Ervin Humphries (left) and Douglas Brock of the Mt. Olive Pickle Company.

More Advances

Important advances continued to flow from the lab after Henry Fleming followed Etchells as research leader from 1977 until 2003. Foremost among these was finding the cause of "bloating"—pockets of gas that balloon up within cucumbers during fermentation—which disqualified as much as one-third of each standard 10,000-gallon production batch from its highest value use as whole pickles. Reducing bloat was an economic revolution for the industry.

Fleming, along with his successor, ARS chemist Roger F. McFeeters, who was research leader from 2003 to 2011, began working on the pickling industry's major environmental problem—disposing of large amounts of brining salt. Brine disposal was one of the factors that helped push California olive pickling and processing out of that state and overseas in the 1980s. Environmental regulations have only continued to tighten since then.

Fleming's and McFeeters's work, which increased brine recycling many fold, is considered the lab's third great revolution, this time both economic and environmental, for the pickling industry.

Today, ARS microbiologist Ilenys Pérez-Díaz and ARS food technologist Suzanne Johanningsmeier are continuing McFeeters's work by replacing brining salt—sodium chloride—with calcium chloride. When it comes to environmental disposal, calcium chloride can be a desirable soil amendment rather than a pollutant.

"Roger McFeeters came up with the idea that sodium chloride could be substituted by calcium chloride to maintain firmness," recounts Pérez-Díaz. "In laboratory studies, we found that it retains firmness in the cucumbers and even speeds up the microbiological work of fermentation. The problem is that in the absence of salt, it also speeds up the microbial activity of spoilage bacteria."

To remedy that, the team tested adding sodium benzoate, fumaric acid, and horseradish extract, which is known to have antifungal properties.

"Our team finally came up with a technology that looked workable and reduced the amount of sodium chloride that would need to be disposed of by up to 80 percent," Pérez-Díaz says.

PEGGY GREB (D1891-1)

SANDRA PARKER (D3178-1)

Microbiologist Ilenys Pérez-Díaz (above) and food technologist Suzanne Johanningsmeier (right) are members of an ARS team that has developed new technology that replaces as much as 80 percent of the sodium chloride in brining liquid with calcium chloride, helping to solve a major environmental disposal problem for the pickling industry.

(D3175-2)

ARS chemist Roger McFeeters (second from right), who led the Raleigh laboratory from 2003 to 2011, discusses pickle making with producers in India, who must meet U.S. safety standards if they want to export their products to the country.

Then they turned to nearby Mt. Olive Pickle Company, the largest independent pickle company in the United States, to try out the technology under commercial conditions. Mt. Olive technical services director Janet Turner says, "We were interested in the ideas because we want to show continued efforts to reduce chloride usage in our processes."

The company started out experimenting with calcium chloride fermentation in eight 55-gallon barrels in 2010. By 2013, Mt. Olive was using the technology in 80 tanks, turning about 66,000 bushels of calcium chloride-fermented cucumbers into hamburger dill chips and several flavors of pickle relishes and salad cubes.

"Working with ARS researchers gave us access to knowledge and lab analyses in the beginning that would have been difficult for our company to obtain on our own," Turner says. "The time and experience of Drs. McFeeters, Pérez-Díaz, and Johanningsmeier and their support staff gave us the confidence to conduct these trials."

Now Pérez-Díaz and Johanningsmeier are working on applying the calcium chloride technology to gherkin pickles that are imported from India. They undergo a 40-day Atlantic transit time packed in vinegar, salt, and sulfite, which is now being considered as an undesirable ingredient for people who are sensitive to it.

"We are designing a system in small jars, reducing the salt and replacing it with calcium chloride and replacing the sulfite with fumaric acid and other natural preservatives. Right now, we are testing at the 40-liter semi-commercial scale," says Pérez-Díaz.

The United States is a major gherkin market, but India also supplies them to many other countries, so improving the health and environmental circumstances of this product could have worldwide impact.—By **J. Kim Kaplan,** ARS.

This research is part of Food Safety (#108) and Quality and Utilization of Agricultural Products (#306), two ARS national program described at www.nps.ars.usda.gov.

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Pickled relishes.

MT. OLIVE PICKLE CO. (D3173-1)

Genetic Mapping of Rust-Resistance Genes in Sunflower

Rust is a serious fungal disease of sunflowers around the world. The disease can significantly reduce sunflower yields and has been increasing in severity in North America in recent years. In 2013, U.S. farmers produced more than 2 billion pounds of sunflowers, worth over $757 million dollars.

Sunflower seeds are predominantly grown as an oilseed crop, but some varieties are specifically grown as "confection" varieties, meaning their kernels are for eating—either raw or roasted.

An economic and environmentally friendly method to control rust is to use resistant cultivars and hybrids. Developing genetically resistant hybrids is the preferred approach for disease management, but few widely effective resistance sources to sunflower rust have been identified.

Agricultural Research Service molecular geneticist Lili Qi, in the Sunflower and Plant Biology Research Unit in Fargo, North Dakota, has screened for resistance genes and genetic markers in sunflower genomes. Her collaborators in the study, which was published in *Theoretical and Applied Genetics,* included Thomas Gulya and Brent Hulke, in the sunflower research unit, and Li Gong and Samuel Markell, with North Dakota State University.

First, Qi and her colleagues identified DNA markers to determine the possible locations of resistance genes on sunflower chromosome 13. Two resistance genes have been mapped by the group—R_{13a} in the confection sunflower line called "HA-R6" and R_{13b} in the oilseed line called "RHA 397."

The USDA inbred line HA-R6 is one of the few confection sunflower lines resistant to rust.

"The genes R_{13a} and R_{13b} are highly effective against all rust races tested so far," says Qi. "The newly developed markers will help in breeding efforts to confer rust resistance to the sunflower genomes and accelerate the development of rust-resistant sunflower hybrids in both confection and oilseed sunflowers."

These genetic findings couldn't come at a better time. In an annual field survey conducted by the North Dakota State University Cooperative Extension Service and the U.S. National Sunflower Association, sunflower rust was found in 60 to 77 percent of surveyed fields. Kernels infected by rust can be damaged and discolored and are therefore unlikely to meet grading standards established by the industry for confection sunflower seeds.

"Yield losses to the disease can occur in the wide range of environments and climatic conditions where sunflowers are grown—from the hot and dry climates of the U.S. Central Great Plains to the cooler and wetter climates of North and South Dakota," says Gulya.

"These lines, HA-R6 and RHA 397, should be very useful in breeding commercial sunflower hybrids with high-level, durable resistance to rust," says Qi.—By **Sharon Durham,** ARS.

This research is part of Plant Biological and Molecular Processes, an ARS national program (#302) described at www.nps.ars.usda.gov.

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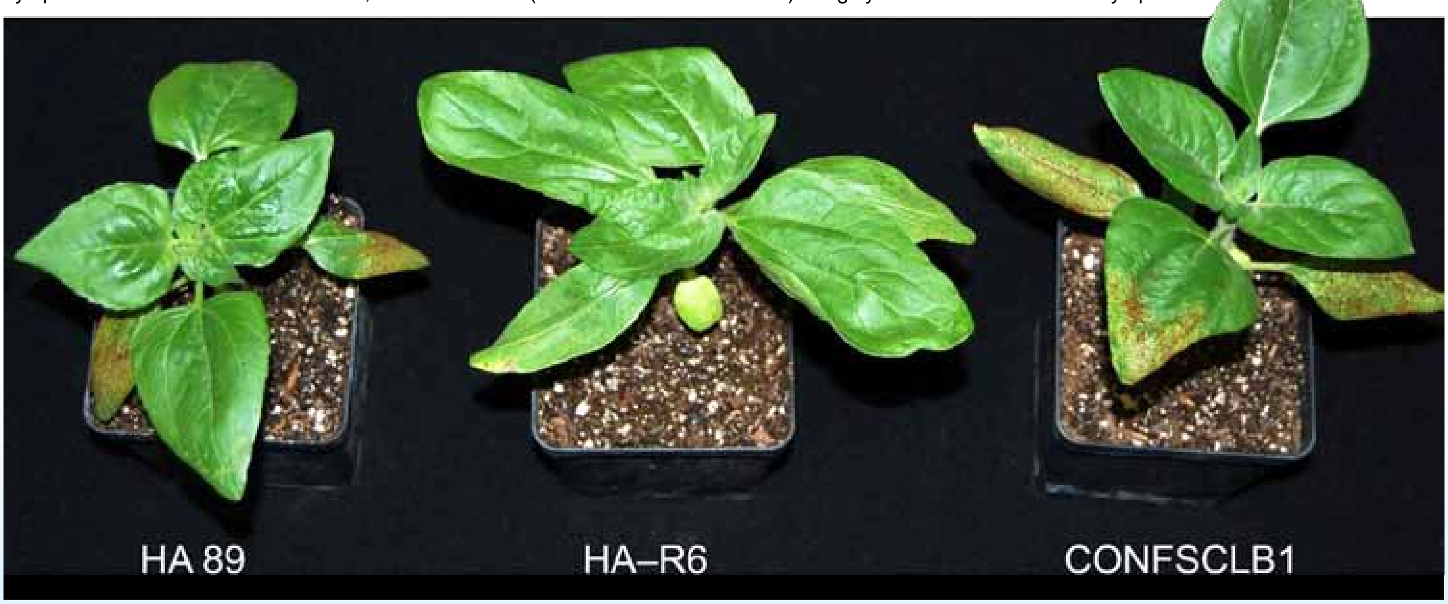
Rust response in three seedling sunflower plants 12 days after inoculation with the most virulent rust race identified so far in the United States. HA 89 (an oil-type sunflower) and CONFSCLB1 (a confection sunflower) are highly susceptible, showing typical symptoms of rust in the infected leaves, whereas HA-R6 (also a confection sunflower) is highly resistant and shows no symptoms.



LILI QI (D3174-1)

Orange-Fleshed Honeydew Melon

Ripe for Beta-Carotene Analysis

PEGGY GREB (D942-1)

Orange-fleshed honeydew melons are an excellent source of beta-carotene and other health-promoting vitamins and minerals.

Eating fruits and vegetables is not often thought of as a "treatment." But according to researchers, there are more than 100 million people worldwide who have vitamin A deficiency, and for some of them, consuming fruits and vegetables is the most available treatment. That's because people in many parts of the world do not have access to vitamin supplements. Select fruits and vegetables contain carotenoids such as beta-carotene, also known as "provitamin A." Beta-carotene is the most potent precursor of vitamin A for humans (meaning the body breaks down beta-carotene into vitamin A).

Two excellent sources of beta-carotene are cantaloupe and the orange-fleshed honeydew melon, which is a cross between cantaloupe and green-fleshed honeydew. The orange-fleshed honeydew melon is sweeter and stores longer than the typical cantaloupe melon.

Little is known about the bioaccessibility and bioavailability of the orange-fleshed melon's carotenoids. Before a consumer can make use of a fruit's nutrients, the nutrients must first be released from the fruit tissues—becoming "bioaccessible"—and then they can be absorbed into the circulation—becoming "bioavailable."

To learn more, Agricultural Research Service plant physiologist Gene Lester and colleagues measured the beta-carotene concentrations in orange-fleshed honeydew and cantaloupe melons grown under the same greenhouse conditions.

The team found that orange-fleshed honeydew had significantly higher beta-carotene concentrations than cantaloupe, but the two melon types had similar beta-carotene bioaccessibilities. This means that both melons appear to be comparable sources of dietary provitamin A for humans, on par with carrots, which are known to be a major source of provitamin A.

In the laboratory, the researchers also tested the bioavailability of beta-carotene from orange-fleshed honeydew melon tissue. Plants store beta-carotene in chromoplasts, and beta-carotene bioavailability is affected by chromoplast structure in plant tissues, such as fruit flesh. Chromoplasts in fruits and vegetables come in different types; globular types provide the best beta-carotene bioavailability, while crystalline types provide less. The researchers found that the chromoplasts in melons are globular—the higher beta-carotene bioavailability type—whereas chromoplasts in carrots, for example, are crystalline.

The team also checked for the presence of apocarotenoids in orange-fleshed melon and cantaloupe. This is significant because apocarotenoids are metabolized directly into vitamin A.

"Previously, we did not know apocarotenoids were in orange-fleshed melons," says Lester. After the researchers first noticed the presence of additional peaks indicating compounds not seen before when testing orange-fleshed melons, they used more sophisticated instrumentation to show that these compounds were apocarotenoids.

Lester's team detected and measured levels of the apocarotenoids beta-apo-13-carotenone, beta-apo-14-carotenal, beta-apo-12-carotenal, beta-apo-10-carotenal, and beta-apo-8-carotenal in the orange-fleshed melons.

Funding support for the study, which was published in the *Journal of Agricultural and Food Chemistry* in 2011, was provided by the U.S. Department of Agriculture and by grants from the National Institutes of Health.—By **Rosalie Marion Bliss,** ARS.

This research is part of Quality and Utilization of Agricultural Products, an ARS national program (#306) described at www.nps.ars.usda.gov.

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STEPHEN AUSMUS (K10428-1)

Making a Barley Fish Feed Product

Agricultural Research Service scientists have formulated a new feed ingredient suitable for rainbow trout (above) and Atlantic salmon. The feed component contains a highly digestible barley protein concentrate produced with technology developed and patented by ARS and an industry collaborator.

For centuries, barley has been used in beverages, soups, stews, breads, and other foods. It also has become a major component in livestock feeds for cattle, sheep, pigs, and other animals. But for fish, barley didn't quite make the grade as a feed ingredient—until now.

The need to develop more plant-based protein sources for aquafeeds is increasing because the availability of small ocean fish, used to make fishmeal and other feeds, remains constant while demand increases dramatically. One of the challenges for fish-feed manufacturers is to procure ingredients that contain enough available protein to meet the dietary needs of fish.

A process that improves the nutritional value of barley has been developed by scientists at the Agricultural Research Service's Small Grains and Potato Germplasm Research Unit in Aberdeen, Idaho, and Montana Microbial Products LLC (MMP) in Missoula, Montana.

"Barley feed grain typically contains about 10-12 percent protein, but an ingredient needs to contain 40-60 percent protein for carnivorous fish like rainbow trout," says ARS fish physiologist Rick Barrows, who is stationed in Bozeman, Montana. "An enzymatic process was developed to concentrate the protein in barley by removing the carbohydrates, which are then turned into an ethanol coproduct, thus utilizing all the nutrients in the grain. The barley protein is not exposed to high temperatures during concentration, so its digestibility is very high."

Scientists tested the barley protein concentrate in rainbow trout to determine its palatability and digestibility—the percentage of nutrients available to the fish. "Protein digestibility and amino acid availability were in the mid-90-percent range," Barrows says.

Barley for Salmon

To evaluate the effects on growth in other fish, research leader William Wolters and fish physiologist Gary Burr, at the ARS National Cold Water Marine Aquaculture Center in Franklin, Maine, fed diets containing barley protein to Atlantic salmon—one of the most widely cultured species in the world. Most salmon diets are about 40 percent protein, scientists say. During a 4-month feeding trial, salmon were fed diets of either 11 percent or 22 percent barley protein concentrate. These fish were compared to salmon fed a standard commercial fishmeal diet. Wolters and Burr found no significant differences in growth among the three groups of fish. However, fish fed the diet containing 22 percent barley protein concentrate had significantly greater energy retention—34 percent—than the fish fed the other diets.

"Energy retention refers to how much energy we are putting into the fish and how much energy is staying in the fish," Burr says. "Fish that have higher energy retention are using the feed more efficiently."

This research, which was published online in the *Journal of Applied Aquaculture* in December 2013, showed that barley protein concentrate is a suitable feed ingredient for salmon and offers an alternative to the more expensive available sources, like fishmeal and soy protein concentrate. A recent collaborative study

STEPHEN AUSMUS (D1422-13)

Fish nutritionist Rick Barrows (right) captures trout from 6-foot-diameter tanks for technician Jason Frost to weigh and measure. These trout were fed fishmeal-free, plant-based feed.

conducted at the University of Sterling in Scotland confirmed that barley protein is a nutritious feed ingredient for salmon, Wolters says.

Commercial Product Ahead

The barley-processing technology has been patented by ARS and MMP. The company received a license for the technology and recently built its first commercial prototype plant in Montana to produce the alternative fish-feed ingredient. The primary purpose is to produce barley protein for use in trout-feeding trials, says MMP's Clifford Bradley.

"Our idea is to run this prototype plant for a year to 18 months and then build the first real commercial facility," he adds. "The testing program will tell us how big we should build the first facility for the commercial product and what the market is going to look like."

That market could be huge, according to Bradley. Aquaculture is still growing very rapidly, so the demand for high-protein ingredients is increasing at a steady rate. Typically, high-protein ingredients are selling at about $1,200 a ton or more, while fishmeal is about $1,600 a ton.

"It's potentially a multibillion-dollar market," he adds.

Counting the Benefits

Besides being less expensive than other protein sources, barley protein concentrate offers other benefits. The phosphorus from bones and fins in fishmeal is not very digestible. "Most of the phosphorus from fishmeal goes into the water as a pollutant," Bradley says. "Barley protein has much less phosphorus, but it is more digestible and better utilized by the fish."

Barley protein concentrate adds to the toolbox of feed manufacturers, reduces cost, and gives farmers an alternative to fishmeal. It also creates additional markets for small-grain growers, Barrows says. For example, the new process is perfect for use with malting barley that is too high in protein, due to weather conditions or other factors, to sell to beer companies.

"We're trying to develop plant-based ingredients for fish so we don't have to rely on fishmeal from the ocean, which has reached its maximum harvestable level," Barrows says. "This helps the environment. Also, if we could produce more fish in the United States with less costly, sustainable ingredients, the American consumer would ultimately benefit from a safe, abundant, and nutritious food source."—By **Sandra Avant,** ARS.

This research is part of Aquaculture, an ARS national program (#106) described at www.nps.ars.usda.gov.

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Details Matter in Modeling Carbon Sequestration and Cropping Systems

Assessing how global climate change might affect soil carbon levels is not a simple matter, in part because accurately measuring current soil carbon sequestration levels—the amount of carbon that is retained in the soil—has its challenges.

"When some people try to measure soil carbon changes, they'll see an increase in total carbon levels and conclude that the carbon has been sequestered. But the carbon hasn't been sequestered until, after decomposition, it becomes attached to soil mineral particles. This process can take several years, depending on the weather," says Agricultural Research Service soil scientist Hero Gollany. "Inaccurate soil carbon measurements can result in overestimates of how much carbon has been sequestered—and until sequestration actually occurs, the carbon can be emitted back into the atmosphere as carbon dioxide."

Developing processes for accurately measuring soil carbon sequestration is a concern for producers, who want to be able to fine-tune agronomic practices and use them in a suite of approaches for mitigating carbon emissions that contribute to global climate change.

One tool for increasing soil carbon sequestration is to reduce fallow periods. Another tool is to use conservation tillage, which also recycles plant nutrients, moderates soil temperature, conserves soil water, controls soil erosion, and provides food and habitat for soil fauna.

Making Sense of the Data

Gollany wrestled with soil carbon measurement protocols when ARS agronomist Frank Young sent data to her from three Pacific Northwest production systems and enlisted her expertise to project how climate change would affect carbon sequestration levels in each practice. The data included carbon levels measured in soils from three crop-rotation systems: winter wheat/reduced-tillage fallow, no-till spring wheat/spring barley, and no-till spring barley/spring wheat.

Gollany works at the ARS Columbia Plateau Conservation Research Center in Pendleton, Oregon, while Young works at the ARS Land Management and Water Conservation Research Unit in Pullman, Washington.

Sequestering and keeping carbon in these dryland soils is particularly difficult because the weather restricts plant growth. As a result, there's a limited supply of postharvest crop residue available to break down and replenish soil carbon levels—and a limited supply of moisture, which means decomposition is a slow process.

Gollany used the computer program CQESTR to generate six 15-year cropping scenarios. CQESTR was developed to calculate how a range of agronomic and weather-related variables could affect crop residue decomposition and soil carbon sequestration levels.

The projections showed a wider range of sequestration levels than expected, depending on the timing of crop residue inputs. To Gollany, these results indicated that the original total soil carbon data varied because it contained accrued—that is, accumulated—plant carbon and not sequestered carbon.

Carbon: Stable or Transitory?

Several methods are commonly used to determine whether carbon is bonded to soil mineral particles. This bonded fraction is considered sequestered and part of the stable soil carbon pool that can remain relatively unchanged for decades, or even centuries.

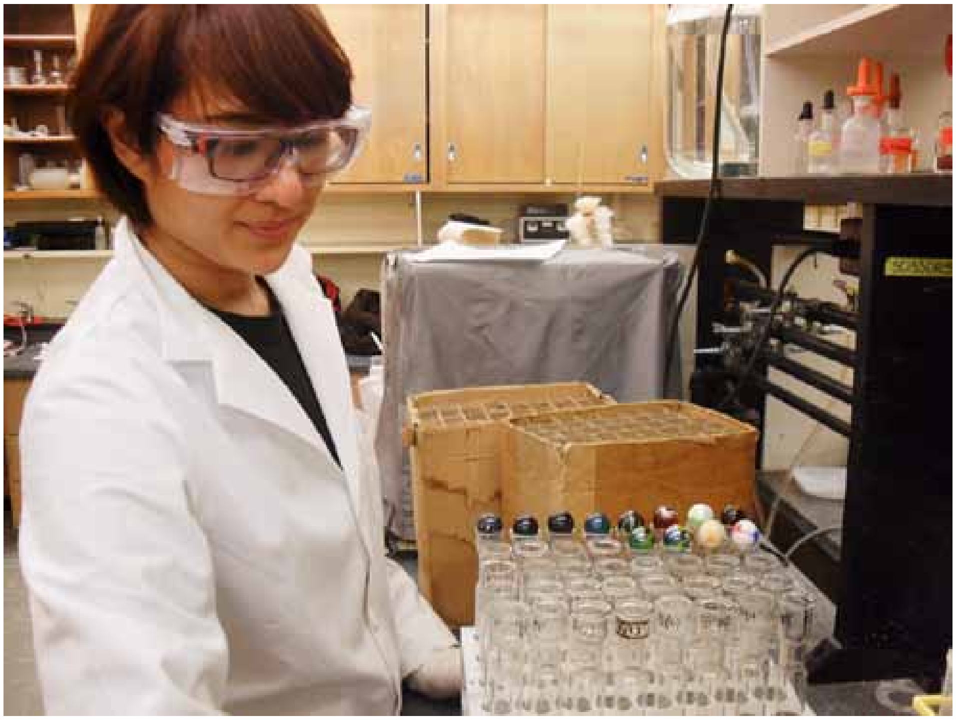
One method is called "light-fraction extraction," and it measures a transitory carbon pool that is somewhere between fresh plant residue and stable soil organic matter. "Light-fraction carbon is found in plant matter that hasn't decomposed yet, so even though it has accrued on the soil, it isn't sequestered," says Gollany. But this transitory carbon is still part of the total soil carbon pool and can improve soil properties for a short period of time, such as a single growing season.

Accrued carbon can readily be lost from the soil because it is not bound to or associated with soil particles. It does

ARS scientists at Pendleton, Oregon, developed a soil carbon model called CQESTR to estimate how climate change will affect soil organic carbon stocks in research plots like this one in Ralston, Washington.

LARRY MCGREW (D3199-1)

ANN-MARIE FORTUNA (D3200-1)



Marshall Samuel, a visiting scientist from Malaysia, performs an analysis for stable soil carbon at Washington State University.

not provide the long-term improvements to soil chemical and physical properties that sequestered carbon provides. And inadvertently adding accrued carbon to measurements of sequestered carbon results in overestimates of how agronomic practices affect sequestration levels.

Gollany and Washington State University soil microbiologist Ann-Marie Fortuna decided to reevaluate the field samples by looking for the light-fraction carbon. Using this method, the scientists determined that carbon levels in the samples included the carbon from fine crop residue materials that passed through the sieves during sample processing—carbon that had accrued in the soil but was not yet sequestered via decomposition.

The light-fraction carbon (as a percentage of total carbon) was higher when measured in the spring than in the fall. This, in turn, skewed attempts to use carbon data from the samples to model soil carbon sequestration levels.

When Gollany adjusted the measured carbon values for these discrepancies, the CQESTR results indicated that as precipitation patterns change, existing winter wheat/fallow systems using current winter wheat varieties might not be feasible for future production in the Pacific Northwest. Even though more precipitation might fall in some regions, the projected changes would not be sufficient to support significantly greater amounts of wheat straw that could add carbon to the soil. The additional soil water and warmer soil temperature might also reduce carbon sequestration rates by increasing residue decomposition, which in turn would accelerate the release of carbon from the residue in the form of carbon dioxide.

"However, our results showed that continuous no-till spring wheat and spring barley cropping would be a good production system for this region, since an increase in spring wheat yield is possible due to early planting if the predicted changes in precipitation patterns and temperatures occur," says Gollany. "That system could benefit from the increased rainfall and produce more plant residue that could eventually boost soil carbon stocks."

Gollany published her findings in 2013 in the *Soil Science Society of America Journal* and says this is the first time light-fraction carbon data has been used to generate CQESTR estimates of soil carbon sequestration.

"There are several key takeaways from this study," Gollany says. "When and how we take soil samples is very important for future climate change studies, to make sure we don't overstate how much carbon we can sequester. We also need to continue to look to no-till production to manage the effects of climate change, and we need to calculate ways we will be able to take advantage of changes in precipitation."—By **Ann Perry,** ARS.

This research is part of Climate Change, Soils, and Emissions, an ARS national program (#212) described at www.nps.ars.usda.gov.

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Winter wheat plots before harvest at Ralston, Washington.

FRANK YOUNG (D3201-1)

DAREN HARMEL (D3198-1)

Reducing Fertilizer Needs by Accounting for Soil Microbes

An ARS technician applies an organic fertilizer source on plots in a study to optimize application rates of organic and inorganic fertilizers. The study is part of efforts to evaluate a new ARS-developed tool for soil testing that can be used to help growers reduce fertilizer use without decreasing yields.

Farmers face a balancing act when deciding how much fertilizer to apply. Applying too much wastes money and adds to nutrient runoff problems. Applying too little reduces yields.

Agricultural Research Service scientists in Temple, Texas, have found a way to help get it just right, maximizing profits, minimizing costs, and saving water bodies from unwanted nutrient runoff. They have developed a test that accurately portrays soil health by determining the levels of naturally occurring nitrogen and other nutrients.

Traditional methods for determining fertilizer needs are based on soil tests developed in the 1960s, which measure the amount of nitrate in the soil. But these tests don't account for the contributions of soil microbes. The microbes play a key role because they mineralize organic nitrogen and phosphate and make them more available to the crop. As a result, farmers often apply more fertilizer than the plants actually need, adding to their costs and causing unnecessary nutrient runoff.

"The problem is that conventional tools are not measuring the right soil characteristics. They test for inorganic nitrogen in the form of nitrate, but that's just one form of nitrogen available to the plant," says Richard Haney, a soil scientist with the ARS Grassland, Soil, and Water Research Laboratory in Temple.

Haney has developed a more integrated approach. Known as the "Soil Health Tool" or "Haney test" in commercial laboratories, it involves drying and rewetting soil and analyzing it in ways that account for microbial activity and measure both nitrate and ammonium, plus an organic form of nitrogen. It also measures organic carbon and other nutrients, in part by replicating some of the natural processes that occur in a field.

The drying and rewetting mimics what happens in the field before and after a rain. Nutrients and other compounds are extracted from the soil samples with both a water-based solution and a solution known as "H3A," which has the organic acids that plant roots use to acquire nutrients from the soil. Growers who use the process receive a spreadsheet that shows the amounts of nitrogen, phosphorus, and potassium available to plants, based on results extracted by both the water- and H3A-based solutions. Results also include measurements of water-soluble organic carbon, water-soluble organic nitrogen, and soil microbial activity, and they provide a calculation of soil health and the ratio of carbon to nitrogen (a key in how much organic nitrogen is released). Organic carbon and organic nitrogen are natural byproducts of microorganisms breaking down the soil. Growers can use the results to determine fertilizer needs.

Savings for Farmers

The Soil Health Tool works for any crop produced with nitrogen or other nutrient fertilizers. Haney has made it available to commercial and university soil-testing laboratories, worked with farmers to promote it, and published several papers detailing its mechanics. The research is funded in part by the Texas State Soil and Water Conservation Board and the U.S. Department of Agriculture's Natural Resources Conservation Service. This enhanced soil-testing process is now offered by laboratories in Maine, Nebraska, and Ohio. It adds to the time and costs for a soil test, but farmers have learned that in the long run it saves on fertilizer costs.

David Brandt, who farms 1,200 acres in Carroll, Ohio, started using Haney's system 3 years ago to estimate the amounts of nitrogen he needed to apply to his corn, soybeans, and wheat fields. He also used it to estimate his phosphorus and potash fertilizer needs.

"I estimate that it's saved us at least 25 percent in nutrient costs," he says. "The readings were more accurate than other soil tests we had run, and we either maintained or increased our yields."

On average, fertilizer costs are reduced by about $10 to $15 per acre by adopting the system, Haney says. With less fertilizer being applied, there is also less nutrient runoff into rivers and bays.

"This means that less of the nutrients are going into the Gulf of Mexico, Chesapeake Bay, and other waterways, where they have been contributing to algae blooms year after year," Haney says.

Works Well With No-Till, Cover Crops

Another problem with conventional soil tests is that they are based on tilled systems used from the 1940s through the 1960s, so they often fall short in providing estimates in cover-crop and no-till systems, which create entirely different soil profiles. Haney's system is able to measure the effects of cover crops and no-till practices. "We can develop a soil health calculation and suggest a cover crop mix," Haney says.

Brandt found that the results helped him understand the contributions made by his cover crops. "We knew they were helping, but we never understood why. This new information gave us a better understanding of what was going on in terms of nutrients in the soil," Brandt says. He used the information to adjust his mix of cover crops and get a better ratio of carbon and nitrogen, a critical factor in soil health. "It's helped us to pick the right cover crops to utilize in the field," he says.

In a 4-year field study conducted with Daren Harmel, research leader of the laboratory in Temple, Haney evaluated the enhanced soil-testing method in fields of wheat, corn, oats, and grain sorghum at nine sites in Texas. They applied fertilizer at traditional rates or at the amounts dictated by the Haney soil tests, and they left some plots unfertilized. They planted and harvested on the same dates at each site and kept track of fertilizer costs, crop prices, and overall profits.

They found that the enhanced method reduced fertilizer use by 30 to 50 percent and reduced fertilizer costs by up to 39 percent. The enhanced method had little effect on corn production profits, but increased profits 7 to 18 percent in wheat, oat, and sorghum fields. The results were published in the *Open Journal of Soil Science* in June 2013.

"We're asking farmers to think about what they're putting on the soil and whether it is necessary. It involves a new way of thinking, but fertilizer costs are rising, so the idea is attracting more interest," Haney says.—By **Dennis O'Brien,** ARS.

This research is part of Climate Change, Soils, and Emissions, an ARS national program (#212) described at www.nps.ars.usda.gov.

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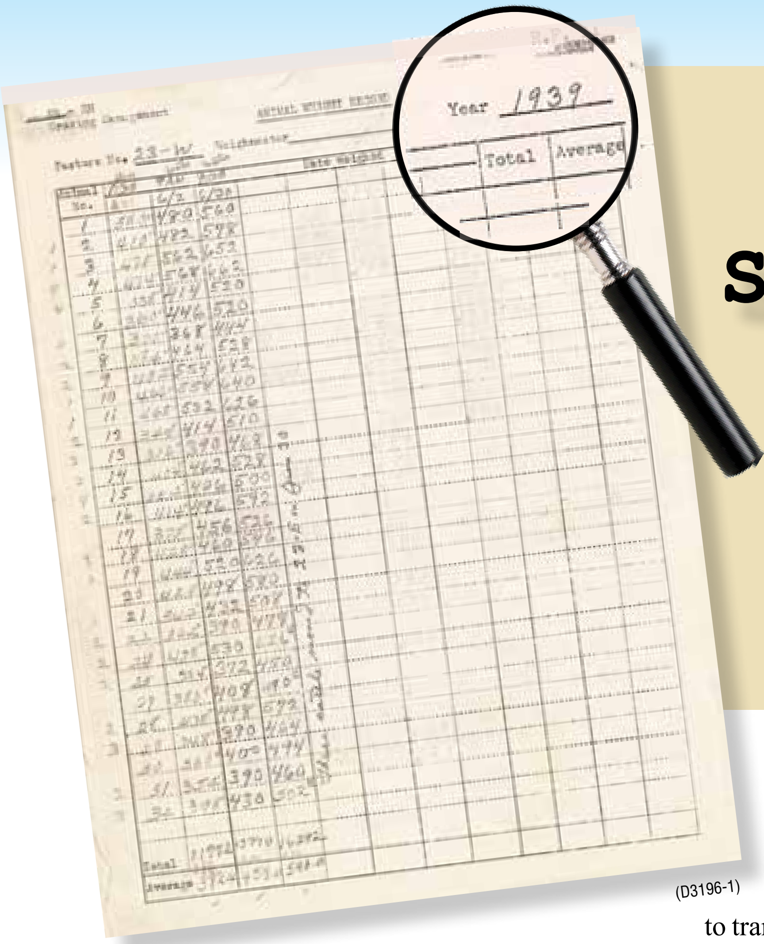
ARS scientists have developed a testing process that accurately measures naturally occurring nitrogen and other nutrients in soil.

PEGGY GREB (D3197-1)



(D3196-1)

Data Analyses Show How Weather Patterns Can Affect Cattle Production

Agricultural Research Service technicians digitized decades of handwritten records on weather, forage production, and cattle production from the Northern Plains. ARS scientists are using this historical data to help livestock producers improve current and future management strategies.

For decades, Agricultural Research Service scientists in the northern plains have kept meticulous records on cattle weight gains during the growing season. Although their main focus was on trends in livestock and forage production, they also tracked weather conditions as part of their studies.

A few years ago, ARS rangeland management specialist Justin Derner assembled a scientific team from three ARS locations in Wyoming, North Dakota, and Montana to study the influence of seasonal weather patterns on cattle production. The team wanted to determine whether past trends could help cattle producers improve management strategies for dealing with future production challenges that might arise from increased seasonal weather variability.

"It's impossible to answer long-term questions about cattle production using short-term data," says ecologist Justin Reeves, who works in the ARS Rangeland Resources Research Unit in Cheyenne, Wyoming, and headed up the analyses. "We need a lot of years and a lot of variation in seasonal weather patterns to accurately determine the effect on cattle production."

The first step was to transfer all the historical written records into electronic databases, a task that took around 2 years. Then, Reeves, Derner, and a team of ARS colleagues began searching for patterns in the long-term data.

In one of their studies, the team determined the effects of seasonal weather variables on cow-calf production in Cheyenne. The cattle production data they used was taken from records kept from 1975 to 2012 on both Herefords and Red Angus crossbred cattle. The crosses generally outweighed the Herefords and on average produced more beef every year, so the breed groups were studied separately.

The weather variables included spring and summer temperatures, spring and summer precipitation, prior winter precipitation, and prior growing season precipitation. An important factor in the research design was using weather variables that would be easily available to ranchers as forecasts. These same weather variables were used in all the studies, which provided consistency and allowed for results to be compared from location to location.

(D3193-1)

Rancher Spud (Frank) Horton (on horse) visits with ARS rangeland scientist Robert Bement during a study to weigh cattle in the 1960s at an experimental range.

(D3190-1)

ANDREW CARRLSON (D3191-1)

Left: A USDA technician collects vegetation samples in Mandan, North Dakota, in 1927. Right: Student intern Allison Haider samples vegetation in the same pasture in 2013. The sampling is part of long-term research on weather, forage, and cattle in Wyoming, North Dakota, and Montana. By combining this data ARS scientists are helping farmers create better long-term cattle production management.

The scientists found that over the study period, up to two-thirds of the variation in Hereford cattle production could be explained by seasonal weather variations. In addition, Hereford cow-calf pairs were potentially more sensitive to seasonal weather variability than the crossbred animals were. For example, under moderate stocking rates, Hereford cow, calf, and pair beef production increased after wet winters and/or wet springs.

The researchers concluded that wet winters and/or wet springs increased soil moisture levels, which likely helped to support an ample supply of forage for livestock throughout the entire growing season.

The Case for Stocking Rate

The team also looked at 30 years of data from yearling steers at Cheyenne to determine if seasonal precipitation and temperature affected beef production at light, moderate, and heavy stocking rates.

The researchers determined that cool, wet springs and warm, wet summers increased beef production at moderate and heavy stocking rates, but not at light stocking rates. These seasonal weather conditions enhanced the growth of both cool- and warm-season forage grasses in the region's northern mixed-grass prairie.

Beef production with light stocking rates was relatively unaffected by seasonal weather variability, because forage was adequate even in years characterized by relatively poor seasonal weather conditions.

The team concluded that seasonal weather forecasts may reduce enterprise risk for ranchers by allowing them to manage forage availability and livestock demand more effectively. This will help ranchers maintain beef production levels and guard against rangeland degradation when conditions are unfavorable for forage growth.

DAVID AUGUSTINE (D3192-1)

Yearling steers grazing on an experimental research pasture of the ARS Rangeland Resources Research Unit.

Invasive Grass Arrives

In a third study, the research team looked at data collected at the Northern Great Plains Research Laboratory in Mandan, North Dakota, from 1936 to 2005. The data was collected on yearling Hereford steer production at light and heavy stocking rates, both before and after the native rangeland was invaded by nonnative Kentucky bluegrass in the 1980s. "Kentucky bluegrass invasion is a problem for many reasons in the Dakotas," Reeves says, "so we wanted to see how the invasion may have affected beef production and its sensitivity to seasonal weather patterns."

Kentucky bluegrass is a cool-season grass that is most productive in early spring, when temperatures are cool and soil moisture levels are relatively high.

When these weather conditions prevail, cattle have earlier and easier access to an abundant supply of forage, which in turn can help boost beef production levels.

The Mandan data suggested that up to three-fourths of the variation in cattle production could be attributed to seasonal weather conditions. Interestingly, cattle production with both light and heavy stocking rates was more sensitive to seasonal weather fluctuations after Kentucky bluegrass arrived. As with the findings from Cheyenne, beef production associated with heavy stocking was more sensitive to seasonal weather variability than beef production with light stocking.

"When you have more cattle, you need more forage," Derner says. "Any impact that weather is having on forage production—and eventual beef production—becomes more pronounced with heavy stocking rates."

During the 70-year study period, greater winter and spring precipitation resulted in more beef production with heavy stocking rates. Although spring temperatures did not affect cattle production prior to the appearance of Kentucky bluegrass, after the plant arrived, hotter spring temperatures resulted in a decline in beef production.

Big-Picture Impact

"The general trends are the same with livestock weight gains at each location, which indicates the relationships we've identified between seasonal weather conditions and cattle production are fairly robust," says Matt Sanderson, research leader at Mandan.

After evaluating their combined results, the researchers concluded that livestock managers can use information about plant communities to determine how projected seasonal weather conditions will affect forage availability—and, by extension, how to adjust cattle stocking rates. This will be particularly useful for producers who periodically want to use heavy stocking rates to optimize profits, since those efforts could be thwarted if seasonal weather conditions end up limiting how much forage is available to meet livestock demands. A long-term goal is to use this information to reduce rancher enterprise risk with the development and dissemination of user-friendly decision-support tools that incorporate free, Web-based, seasonal weather forecasts.

"Our retrospective look at weather variables that have influenced production may begin to help us make projections 10 to 40 years out. This could help cattle producers think about ways they can adapt their production systems to prepare for the impacts of increasing weather variability," says Derner.

The scientists have published their findings in *Rangeland Ecology and Management; Livestock Science;* and *Agriculture, Ecosystems & Environment*.

"There are very few long-term cattle data sets like these, and they are an invaluable resource," notes Reeves. "ARS scientists had incredible foresight to keep collecting consistent data for so long."—By **Ann Perry,** ARS.

This research is part of Pasture, Forage, and Rangeland Systems (#215) and Climate Change, Soils, and Emissions (#212), two ARS national programs described at www.nps.ars.usda.gov.

To reach the scientists mentioned in this story, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville MD 20705-5128; (301) 504-1628, ann.perry@ars.usda.gov.

Weather and Weight

Ecologist Lance Vermeire and animal scientist Mike MacNeil (retired) conducted a related study that used 76 years of data to evaluate links between weather patterns and the growth of Hereford calves at the ARS Fort Keogh Livestock and Range Research Laboratory in Miles City, Montana. Their data was unique; all the animal records were obtained from one closed and pedigree-recorded population that has been maintained at the Miles City location throughout its history.

VICKI LEESBURG (D3189-1)

Using 76 years of data on weather and the growth of Hereford calves in Miles City, Montana, ARS scientists concluded that a general increase in temperature could result in decreased growth of suckling calves.

The scientists found that calves reared in years with longer, cooler growing seasons and typical seasonal precipitation grew faster from birth to weaning than calves reared under other conditions, regardless of previous seasonal precipitation patterns. In the model, they identified two critical weather periods that affected weight from birth to weaning. Additional precipitation from February 8 to February 22—almost certainly in the form of snow—reduced weight gain by nearly 3.4 pounds per 1/10 inch of precipitation. Vermeire and MacNeil think the pregnant cows, which became increasingly wet as the snow accumulated, responded to the wintry conditions with a decrease in body temperature that affected the unborn calves.

During the second critical weather period, from June 23 to July 7, model results indicated that every 1˚F increase in temperature reduced growth from birth to weaning by around 1.1 pounds. Since 90 percent of annual plant productivity for this region typically occurs by July, the researchers think the increasing temperatures reduced forage quality by speeding up the rate of plant senescence and reducing forage digestibility and nitrogen content. These results indicated that a general increase in temperature could result in decreased growth in suckling calves in the U.S. northern Great Plains, the scientists say. This research was published in *Agricultural Sciences* in 2012.

Whacking Weeds Organically

DEAN PETERSON (D3204-1)

This tractor-mounted system uses compressed air to spray corn grit onto weeds growing between four rows of crops simultaneously. Nozzles work in pairs to control small weeds by shredding them. ARS scientists were able to control 80-90 percent of weeds with two grit applications at two crop growth stages.

DEAN PETERSON (D3203-1)

It can take real grit to control tenacious weeds. Although determination is an important attribute in farmers, Agricultural Research Service agronomist Frank Forcella is counting on grit of another kind in his approach to battling weeds.

In collaboration with South Dakota State University (SDSU) researchers, Forcella has devised a tractor-mounted system that uses compressed air to shred small annual weeds, like common lambsquarters, with high-speed particles of grit made from dried corncobs. Ongoing field trials may foretell of the system's potential to help organic growers tackle within-row infestations of weeds that have sprouted around the bases of corn, soybean, and other row crops.

Dubbed "Propelled Abrasive Grit Management" (PAGMan), the system disperses 0.5-millimeter-sized grit particles in a cone-shaped pattern at the rate of about 300 pounds per acre, using 100 pounds per square inch of compressed air. An SDSU engineering team built the machine under a grant Forcella was awarded from the U.S. Department of Agriculture's National Institute of Food and Agriculture.

"For the first few weeks of the growing season, weeds are relatively small, and that's when we target them with the grit," says Forcella, at the ARS North Central Soil Conservation Research Laboratory in Morris, Minnesota. The crop plants escape harm because they are taller than the weeds, and their apical meristems (growing points) are protected beneath the soil or by thick plant parts.

Current organic weed control methods include flaming (or scorching), soil tillage, and hand-pulling, among others. Still, weeds remain a chief agronomic concern requiring new approaches, says Forcella.

This summer will mark a second round of field tests of PAGMan on multiple rows of silage corn grown on 10-acre plots of certified organic land in Minnesota. "Last year, in corn with its full complement of weeds, we were able to get season-long weed-control levels of 80 to 90 percent using two treatments of the abrasive grit—one at the first-leaf stage and the second at the three- or five-leaf stage of corn growth," Forcella says. Corn yields compared favorably to those in hand-weeded control plots.

Initially, PAGMan consisted of a hand-held nozzle and compression hose hitched to a grit-filled tank on the back of an all-terrain vehicle. The tractor-mounted version, built by SDSU professor Daniel Humburg and former graduate student Cory Lanoue, uses an air compressor to pump the grit through eight custom-made nozzles capable of covering a four-row area.

"We use corncob grit for our tests, but other agricultural residues could also be used," Forcella says. Organic growers suggested using corn gluten meal as a way to fertilize crops and blast weeds simultaneously. "We tried corn gluten meal and found it just as effective. The amounts necessary for controlling weeds were similar to those used to supply nitrogen to organic crops."

Forcella has published results from earlier, small-plot studies in *Weed Technology* and other peer-reviewed journals. Results from the 2013 field trials were presented this year at the Weed Science Society of America's annual meeting by SDSU graduate student Mauricio Erazo-Barradas and professor Sharon Clay.—By **Jan Suszkiw,** ARS.

Below: Ground corn grit that can be sprayed on weeds to shred their leaves. Each grit grain is about 0.5 millimeters in diameter.

(D3206-1)

This research is part of Crop Production, an ARS national program (#305) described at www.nps.ars.usda.gov.

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Treatment Has Potential To Reduce Allergenicity of Peanuts

A phytochemical compound—tannic acid—may be an effective scavenger of peanut allergens, according to a study by Agricultural Research Service food technologist Si-Yin Chung and support scientist Shawndrika Reed. They are in the Food Processing and Sensory Quality Research Unit, which is part of the Southern Regional Research Center in New Orleans, Louisiana.

In people who are allergic to peanuts, the immune system reacts to amino acid sequences, or proteins, in the peanuts. The study provides insights into whether tannic acid can be used during food processing to reduce the allergenicity of peanut-based foods and beverages.

"We also wanted to see if this compound can help reduce or prevent allergic responses that are induced when people accidentally ingest peanut residues contained in food products," says Chung.

Tannic acid, or tannin, is a phenolic antioxidant commonly found in legumes, coffee, tea, and certain tree barks. It has been shown to bind to allergenic protein fragments, forming insoluble complexes that may keep the allergenic protein from being released in the stomach and gut.

Chung wanted to see whether mixing tannic acid with major peanut allergen proteins (Ara h 1 and Ara h 2) would form stable complexes (pellets) that could prevent release of the peanut allergens in the human stomach and gut. If so, an allergic reaction could be reduced or possibly prevented. Allergic reaction occurs when an antibody called "immunoglobulin E" binds to the allergenic protein fragments, leading to the release of histamines.

For the study, Chung mixed four different levels of tannic acid in peanut butter extract. The pellets that were formed and collected were each tested in a solution at the acidic level of the human stomach (pH 2) and then in another solution at the alkaline level of the intestines (pH 8). The solutions were then analyzed for allergens that might be released from the pellets under those pH conditions.

The tannic acid levels were 0.25, 0.5, 1, and 2 milligrams (mg) per milliliter of peanut butter extract. Results showed that the pellets formed at tannic acid concentrations greater than 0.5 mg per milliliter of peanut butter extract did not release major peanut allergens at either pH level. The authors concluded that these bound allergens should pass through the gastrointestinal system without being absorbed, and therefore they would not cause an allergic reaction.

"The precise level of tannic acid that is needed to prevent allergic reaction, without altering food flavor or reducing protein levels in the food, still needs to be worked out," says Chung.

While proof-of-concept animal-model studies and tests for safety and efficacy still need to be conducted before tannic acid can be used to develop less allergenic peanut products, says Chung, the study shows that tannic acid holds promise as a scavenger that binds to allergenic peanut proteins and keeps those proteins from being released in the stomach and gut after ingestion.

The study was published in *Food Chemistry* in 2012.—By **Rosalie Marion Bliss,** ARS.

This research is part of Quality and Utilization of Agricultural Products, an ARS national program (#306) described at www.nps.ars.usda.gov.

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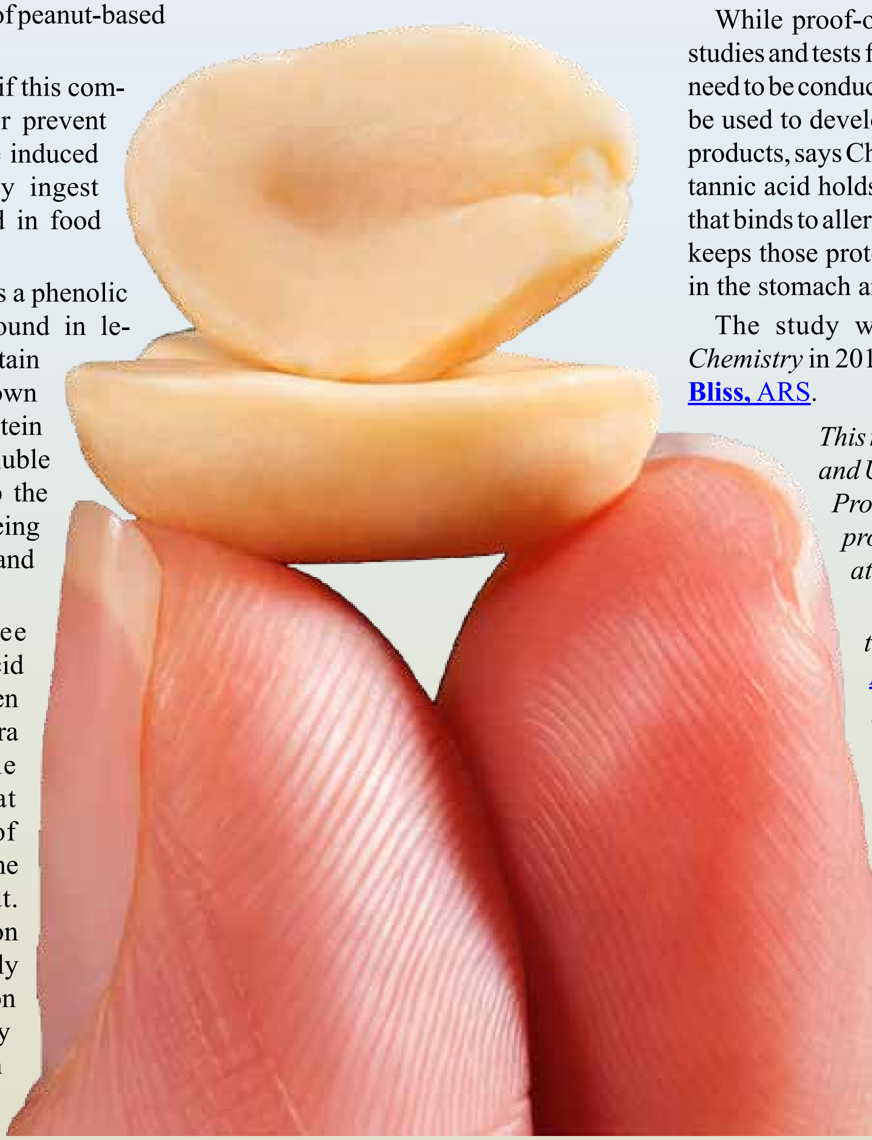

ARS scientists found that tannic acid can bind to allergenic peanut proteins, potentially reducing the chances of an allergic reaction.

PEGGY GREB (D3202-1)

The Agricultural Research Service has about 100 labs all over the country.

Locations Featured in This Magazine Issue

Locations listed west to east.

Map courtesy of Tom Patterson, U.S. National Park Service

Albany, California
8 research units ■ 202 employees

Columbia Plateau Conservation Research Center, Pendleton, Oregon
1 research unit ■ 18 employees

Pullman, Washington
6 research units ■ 110 employees

Small Grains and Potato Germplasm Research Unit, Aberdeen, Idaho
1 research unit ■ 41 employees

Logan, Utah
3 research units ■ 73 employees

Livestock and Range Research Laboratory, Miles City, Montana
1 research unit ■ 20 employees

High Plains Grasslands Research Station, Cheyenne, Wyoming
1 research unit ■ 27 employees

Northern Great Plains Research Laboratory, Mandan, North Dakota
1 research unit ■ 31 employees

Grassland Soil and Water Research Laboratory, Temple, Texas
1 research unit ■ 26 employees

Red River Valley Agricultural Research Center, Fargo, North Dakota
5 research units ■ 141 employees

North Central Soil Conservation Research Laboratory, Morris, Minnesota
1 research unit ■ 32 employees

Southern Regional Research Center, New Orleans, Louisiana
6 research units ■ 160 employees

Raleigh, North Carolina
4 research units ■ 60 employees

Henry A. Wallace Beltsville Agricultural Research Center, Beltsville, Maryland
27 research units ■ 806 employees

Eastern Regional Research Center, Wyndmoor, Pennsylvania
6 research units ■ 213 employees

National Cold Water Marine Aquaculture Center, Franklin, Maine
1 research unit ■ 9 employees