U.S. Department of Agriculture | Agricultural Research Service | May/June 2011

Agricultural Research

Like Blueberries?

Thank USDA.

pages 2, 4-16

Agricultural Research Service
Solving Problems for the Growing World

The Delightful Domesticated American Blueberry: Some Research Challenges For Its Next 100 Years

MARK EHLENFELDT (D2210-1)

Featured in many garden catalogs and magazines this spring, Pink Lemonade was developed as part of ARS's blueberry breeding program at Chatsworth, New Jersey.

As their millions of fans around the country will happily tell you, America's blueberries are delicious and good for you.

There are many unseen steps in the journey of this popular berry as it makes its way from growers' fields to you. For every major region in which commercial blueberries are grown, Agricultural Research Service blueberry researchers provide new scientific findings to help smooth this journey.

Blueberry growers everywhere need highly productive kinds of blueberries to plant; safe, effective ways to protect the plants from insects and diseases; and efficient, environmentally responsible ways to apply water and fertilizer so that their blueberry bushes—and the environment—will prosper. Consumers need readily available, affordably priced blueberries, plus evidence-based data about the true nutritional benefits of this much-loved fruit. At labs from coast to coast, ARS scientists are addressing all of these needs.

The remarkable story of the domesticated American blueberry began 100 years ago with the pioneering work of U.S. Department of Agriculture botanist Frederick Coville. His research led to the blueberry's domestication and to several blueberry varieties still popular today. We have built on and expanded his work and today have scientists working in Chatsworth, New Jersey; Poplarville, Mississippi; and Corvallis, Oregon, to develop new blueberry varieties that will thrive in these regions.

Our blueberry genebank in Corvallis and our blueberry genomics research there and in Chatsworth and in Beltsville, Maryland, provide tools and resources to quickly and accurately locate and move highly desirable traits, such as disease resistance, from blueberry's wild relatives into superior new blueberries that have the characteristics growers and consumers prefer.

When exciting new blueberries are developed, that progress brings a renewed need for scientifically sound, effective, and affordable management strategies for producing them.

We're on the job.

In Corvallis, for example, our 6-year-long investigation of various methods for irrigating blueberries, and for scheduling those irrigations, has identified practices that not only maximize yield and berry quality, but also conserve water and fertilizer. Plans call for publication of this practical, thoroughly researched information in an up-to-date irrigation guide for blueberry growers of the Pacific Northwest.

There's another important dimension to our blueberry research. Preliminary investigations into the potential role of blueberries in helping protect against a number of human health problems are under way in Albany, California; Beltsville, Maryland; Boston, Massachusetts; Little Rock, Arkansas; and Oxford, Mississippi. Our research on the role of blueberries in human nutrition is still very preliminary since it has, for the most part, been based on results from studies that used lab animals, cultured cells, or both. Follow-up studies with humans are of course needed before we can make definitive statements about blueberries' effects.

In the meantime, keep eating blueberries! Besides tasting good, they fit in well with the advice to "eat five a day." Blueberries supply many nutrients, such as vitamins, and many lesser-known compounds—called "phytochemicals"—that do not have a specified nutritional role but may be involved in a host of different, and important, functions.

The worldwide epidemic of obesity makes eating fruit especially important. Nutritionists agree that, in the United States, we eat too much sugar and fat and too many calories. Nutritionists also agree that we can help fix this problem by eating more whole fruits—and vegetables, too.

If our ongoing nutrition research is confirmed in humans, blueberries may indeed be shown to provide protection against some common health problems.

In the future, it may be possible to integrate what we learn about blueberries' nutritional benefits with what we discover about their production, making tomorrow's berries better than ever on both fronts. That would benefit both our health and the economic well-being of the growers who make it possible for us to enjoy this delightful fruit.

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Solving Problems for the Growing World

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Is this ARS scientist sprinkling freeze-dried blueberries, or is she sprinkling a placebo that looks, tastes, and smells the same?

Why did ARS scientists make the placebo?

See story on page 10.

PEGGY GREB (D2188-1)

Cover: Blueberries are popular and versatile—you can put them in or on almost anything. But the berry would not be where it is today without the efforts of a USDA researcher in the early 1900s (story begins on page 14). Today, ARS scientists are busy solving growers' problems with blueberry disease, firmness, splitting, and cold tolerance (story begins on page 4) and studying healthful nutrients from this delicious fruit (story begins on page 9). Photo by Stephen Ausmus. (D2201-2)

Blueberries

Making a Superb Fruit Even Better!

When U.S. Department of Agriculture botanist Frederick Coville started the world's first successful blueberry breeding program, did he envision it would grow into the multi-million dollar industry it is today? Maybe. But a century later, thanks to dedication by Coville, collaborator Elizabeth White, and other USDA and university scientists, blueberries are the second most popular berry consumed in the United States.

A member of the genus *Vaccinium,* blueberries are related to many commercially important and popular fruit species, like cranberry, lingonberry, and huckleberry. Blueberries are mainly native to North America and are lauded for their health benefits.

PEGGY GREB (D2182-1)

Plant geneticist Mark Ehlenfeldt (left) and plant pathologist James Polashock examine blueberry plants and collect data on mummy berry fruit infection to evaluate resistance.

Coville began researching blueberries in 1906, when he started a series of experiments to learn fundamental facts about them, thinking they might be suitable for cultivation. Coville found that blueberries and many other plants require acid soils to grow, a fact not known to horticulturists prior to his experiments.

After a few years of study, Coville published in 1910 the first bulletin outlining how to successfully grow blueberries from seed to fruit. White, whose family at that time had a successful cranberry farm in New Jersey, helped Coville acquire some of the best wild blueberry plants to use as parents in his breeding experiments.

In 1911, Coville made the first cross of wild blueberry germplasm that eventually led to the release of several blueberry cultivars—ancestors of cultivars currently grown throughout the world—marking the beginning of USDA's current breeding program.

Throughout the years, notable Agricultural Research Service blueberry breeders George Darrow, Donald Scott, and Arlen Draper have made significant contributions to the advancement of blueberries. Today, 100 years after Coville made his first successful cross, ARS researchers throughout the country continue the longstanding goal of improving blueberries so consumers can enjoy them for many more centuries to come.

Mitigating Mummy Berry Blight and Fruit Rot

Geneticist Mark Ehlenfeldt and plant pathologist James Polashock are researching mummies—mummified blueberries, that is, which got that way because of a disease. The scientists are with the Genetic Improvement of Fruits and Vegetables

Laboratory in Beltsville, Maryland, and are stationed at the Philip E. Marucci Center for Blueberry and Cranberry Research and Extension in Chatsworth, New Jersey. One of ARS's flagship locations for blueberry research, Chatsworth houses the largest collection of potted and in-ground blueberry cultivars in the world.

In addition to releasing improved blueberry varieties, the researchers focus on screening for disease resistance, and mummy berry is one of the most important blueberry diseases in North America.

"Mummy berry is caused by the fungus *Monilinia vaccinii-corymbosi*," says Polashock. "It occurs almost everywhere blueberries are grown and affects all cultivated species, including highbush, lowbush, rabbiteye, and some wild species."

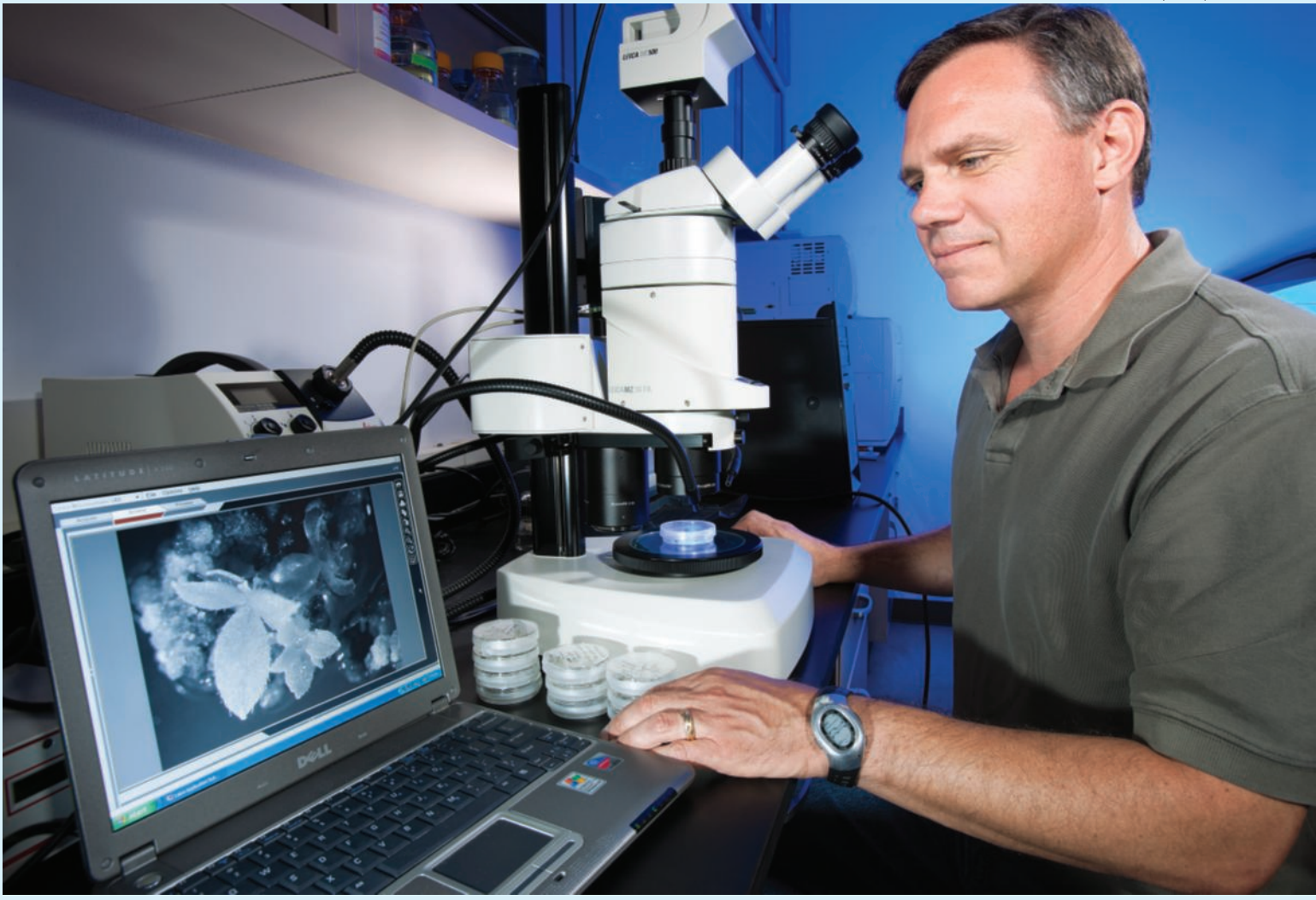
Mummy berry disease is unique because it occurs in two distinct phases. During the blighting phase, small, cup-shaped structures bearing fungal spores sprout from mummified berries concealed in leaf litter on the ground. Wind spreads the spores to blueberry plants, infecting the newly emerging shoots and leaves. A second phase of spores, produced on blighted tissue, is carried by bees to the flowers, beginning the fruit-rotting stage. During this phase, the fungus fills the inside of the blueberry as it grows and causes it to shrink, shrivel, and turn whitish—hence the mummy reference. The mummified fruit drops to the ground and overwinters, waiting to begin the process again in the spring.

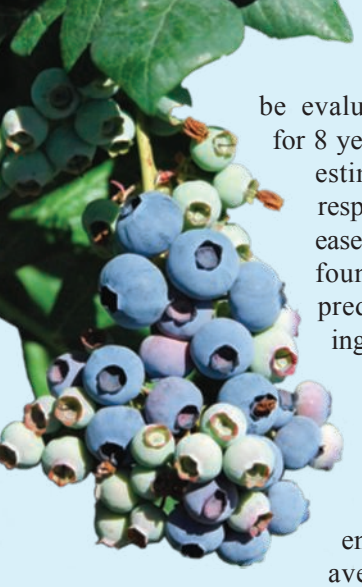
In an effort to mitigate this disease, Ehlenfeldt, Polashock, plant pathologist Allan Stretch (now retired), and statistician Matthew Kramer undertook two long-term, simultaneous studies examining cultivar response. The first study, published in the scientific journal *HortScience,* sought to predict cultivar resistance and susceptibility to both phases of the disease. The scientists examined more than 90 blueberry cultivars over 9 to 12 years.

"We found that disease response had significant and large genotype-by-environment interactions," explains Ehlenfeldt. "This means that the 2-3 years of data typically used for publication aren't enough to reliably estimate disease resistance. Breeders should

James Polashock screens blueberry tissue cultures for plantlets that have transformed, or changed, their genetic makeup. These plantlets are easy to identify because they express a green fluorescent protein and glow under UV light in the procedure being used. In these transformed plantlets, the genes that respond to the fungus that causes mummy berry are likely to provide clues to resistance to the disease.

PEGGY GREB (D2181-1)





be evaluating resistance for 8 years to get a good estimate of cultivar response to this disease." The researchers found an important predictor of blighting to be either the average amount of precipitation at the end of January or rain frequency at the end of March. The average high temperature in late February was predictive for the fruit-infection phase.

Despite predictions of needing 8 years to estimate disease resistance, a second study, also published in *HortScience,* analyzed data from 125 cultivars tested for 2-6 years for resistance to the blighting phase and 110 cultivars tested for 2-5 years for resistance to the fruit-infection stage. Using innovative statistics developed by Kramer, the researchers were able to rank resistances among the wide range of cultivars. "For breeding, one often needs only to know which cultivars are the most resistant on a relative basis," says Ehlenfeldt. They found several cultivars, such as Brunswick and Bluejay, to be resistant to both phases of mummy berry infection.

"Ultimately, documentation of resistance to each phase will help growers select which cultivars to plant," says Ehlenfeldt. "This will also help breeders develop strategies to produce cultivars with superior resistance."

Preventing Fruit Splitting

The Thad Cochran Southern Horticultural Laboratory in Poplarville, Mississippi, joined ARS's blueberry research program in the 1970s. Led by horticulturist James Spiers (now retired), the program was started after the region's tung oil industry collapsed because of competition from imported petroleum and a devastating blow from Hurricane Camille in 1969. "Rabbiteye blueberries are native to the Southeast," says Spiers. "ARS has also introduced a southern highbush blueberry to the region. Combined, the two blueberry species have proven to be a viable specialty crop for this area."

So far, Poplarville scientists have released 15 cultivars for growers in the Southeast. But that's not all they do. The researchers also focus on solving problems growers face, such as rain-induced fruit splitting.

"Splitting and cracking occur in southern highbush and rabbiteye blueberries if they receive preharvest rainfall when fully ripe or approaching ripeness," explains horticulturist Donna Marshall. She works with Spiers, geneticist Stephen Stringer, and University of Southern Mississippi associate professor Kenneth Curry on this problem. "Researchers have studied rain-induced splitting in cherries, grapes, and tomatoes, but it hasn't been explored in blueberries."

Splitting can be mild, in the form of a shallow crack in the skin, to severe, such as deep wounds that penetrate the pulp. But regardless of severity, all splitting renders the fruit unmarketable. Growers in Mississippi and Louisiana have reported as much as 20 percent crop loss on highly susceptible cultivars. That amounts to losses of $300 to $500 per acre.

The researchers examined several aspects of fruit splitting in three studies published in *HortScience.* In the first study, published in 2007, the researchers developed a laboratory method to model rain-related splitting in blueberries. Many breeders throughout the country are using this method to more vigorously screen cultivars and selections for splitting susceptibility. The results from field and

PEGGY GREB (D982-1)

Horticulturist Donna Marshall measures blueberry firmness to determine the correlation between fruit firmness and susceptibility to fruit splitting.

laboratory tests showed that the rabbiteye cultivar Premier had the lowest incidence of splitting while widely grown cultivar Tifblue exhibited a high incidence of splitting.

Marshall and colleagues also investigated the correlation between splitting susceptibility and fruit firmness. Laboratory and field tests proved that, in general, firmer fruit has a higher tendency to split. But one selection, named "MS614," exhibited extreme firmness and splitting resistance. The results, published in 2008, suggest that breeders who select for firmness may inadvertently also be selecting for splitting. But the laboratory screening method Marshall and colleagues created has helped remedy this problem.

The most recent study, published in 2009, evaluated water-uptake thresholds in split-resistant Premier and split-susceptible Tifblue fruit at all stages of development. The researchers harvested and weighed the fruit, then soaked it in distilled water at room temperature for 24 hours. They found that Premier absorbs more water than Tifblue yet remains intact and experiences minimal splitting.

"Through our studies, we've shown that splitting is a cultivar-specific problem," says Marshall. "But there are still questions, such as what is going on at the cellular level that allows a cultivar to stay intact? With further research, we hope to find the answer."

Generating Genomic Tools for Blueberry Improvement

Geneticists Chad Finn, with the ARS Horticultural Crops Research Unit, and Nahla Bassil, with the ARS National Clonal Germplasm Repository—both in Corvallis, Oregon—are developing and

An example of rain-induced splitting, a problem that can lead to losses of up to 20 percent on highly susceptible cultivars.

Blueberries of the World Housed in Unique Collection

Blueberries from throughout the United States—and more than two dozen foreign countries—are safeguarded at America's official blueberry genebank. Located in Corvallis, Oregon, this extensive living collection includes domesticated blueberries and their wild relatives, carefully maintained as outdoor plants, potted greenhouse and screenhouse specimens, tissue culture plantlets, or as seed.

The genebank's purpose is to ensure that these plants, and the diverse gene pool that they represent, will be protected for future generations to grow, study, improve, and enjoy. Plant breeders, for example, can use plants from the collection as parents for new and even better blueberries for farm or garden.

Blueberries and several other berries are among the fruit, nut, and specialty crops housed at what's officially known as the ARS National Clonal Germplasm Repository-Corvallis. The repository is part of a nationwide, ARS-managed network of plant genebanks.

Likely the most comprehensive of its kind in the world, the blueberry collection nevertheless continues to expand, according to research leader Kim E. Hummer. Some acquisitions, referred to as "accessions," are donations from breeders. Others are acquired through collecting expeditions, which have taken plant explorers to, for example, Russia, China, Ecuador, and Japan, as well as throughout the United States.

"We have focused on collecting blueberry relatives that may have immediate use for U.S. breeders," says Hummer. "For example, we've acquired native species of wild blueberries from the Pacific Northwest that bear fruit with pigmented flesh, or pulp. Some breeders are trying to breed some of these species into the familiar highbush blueberry that has a white interior. If breeders can put color on the inside of berries through crossbreeding the internal-color berries with the highbush plant, they may be able to produce a blueberry that gives fuller color to processed blueberry products, such as jams, jellies, juice, and dried or frozen fruit."

Other prized specimens at the genebank may someday become landscaping favorites. "We have *Vaccinium praestans,* or redberry Kraznika, from Russia, China, and Japan," says Hummer. "It's low growing and is called 'rock azalea' in Japan. This red-fruited berry plant is suitable for northern latitudes and would be an interesting and attractive ground cover that comes complete with edible fruit." —By **Marcia Wood,** ARS.*

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CHAD FINN (D2195-2)

CHAD FINN (D2195-3)

ARS researchers in Corvallis, Oregon, are developing and improving blueberries for the Pacific Northwest. Above are Elliott blueberry plants in full bloom. Inset: Close-up of blueberry flowers.

improving blueberries for the Pacific Northwest. Although Corvallis is the most recent ARS location to conduct blueberry breeding, Finn and Bassil are playing an important role in a nationwide, multi-institutional project aimed at developing genomic tools to help improve blueberries.

Funded by the Specialty Crops Research Initiative, the project is led by fellow ARS geneticist Jeannie Rowland in Beltsville, Maryland, and involves several university and international collaborators. Finn and Bassil are working with Michigan State University professor James Hancock in developing a genetic map for highbush blueberry.

"We are currently testing plants made from a cross between the northern highbush cultivar Draper and the southern highbush cultivar Jewel at various locations across the country where blueberry is grown," says Finn. "Our task is to compare the performance of each plant in the field. For the next couple of seasons, we will evaluate the plants for chilling requirement, cold tolerance, and fruit-quality traits."

In the lab, Bassil is processing leaf samples to extract DNA and genotype the plants. The researchers will then merge the field and lab data to determine whether genetic markers that predict a plant's performance can be identified. Bassil is also helping to develop genetic markers and following them through mapping populations and wild blueberry populations for genetic diversity studies.

The new tools, once available, should make blueberry breeding and cultivar development far more efficient.—By **Stephanie Yao,** formerly with ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301), Plant Diseases (#303), and Crop Production (#305), three ARS national programs described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Robert Sowers, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1651, robert.sowers@ars.usda.gov.

Fruit cluster of Draper, a cultivar released by Michigan State University and named in honor of Arlen Draper, a long-time blueberry breeder with ARS in Beltsville, Maryland.

CHAD FINN (D2195-1)

Blueberries and Your Health: Scientists Study Nutrition Secrets of Popular Fruit

No doubt about it. America loves blueberries. We each eat about three times more fresh blueberries today than we did 10 years ago.

Blueberries pack a lot of nutritional punch: They're low in calories and rich in vitamin C.

Studies by Agricultural Research Service scientists are expanding our science-based knowledge of this plump little fruit. The research, conducted primarily with laboratory animals or cell cultures, may provide a useful foundation for follow-up studies with humans. Such clinical trials are essential in order to determine whether responses to blueberry compounds observed in lab animals or cells also occur in people.

Hamster Study Examines Blueberries and Cholesterol

ARS chemist Wallace H. Yokoyama, for example, is studying gene-based mechanisms that may explain cholesterol-lowering effects seen in laboratory animals. He is with the agency's Western Regional Research Center in Albany, California.

Yokoyama, along with former postdoctoral research associate Hyunsook Kim at Albany and chemist Agnes M. Rimando, at Oxford, Mississippi, collaborated in a recent study using laboratory hamsters. "Hamsters make a good model for our research because they, like us, can develop high cholesterol from eating high-fat foods," says Yokoyama.

All the hamsters were fed high-fat rations. For some of the animals, the rations were supplemented with one of three different kinds of blueberry juice byproducts: blueberry skins (peels) left over after the berries were pressed for juice and then freeze-dried for the experiment; fiber extracted from the peels; or natural compounds known as "polyphenols," also extracted from the peels. Blueberry polyphenols give the fruit its purple, blue, and red coloration.

PEGGY GREB (D2191-1)

At ARS's Western Regional Research Center in Albany, California, chemists Wallace Yokoyama (left) and Glenn Bartley use real-time PCR to analyze the activity of lab animal genes that may affect cholesterol level.

In an article published in a 2010 issue of the *Journal of Agricultural and Food Chemistry,* the scientists reported that all the hamsters that were fed blueberry-enhanced rations had from 22 to 27 percent lower total plasma cholesterol than hamsters whose feed wasn't spiked with blueberry juice byproducts.

Levels of VLDL (very low density lipoprotein)—a form of "bad" cholesterol—were about 44 percent lower in the blueberry-fed hamsters.

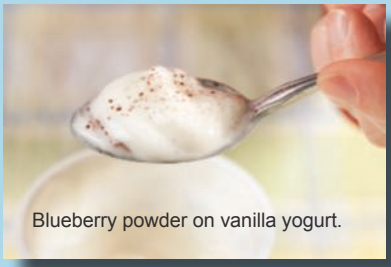
To learn about the genetic mechanisms responsible for these effects, the scientists used a procedure known as "real-time reverse transcription polymerase chain reaction." The approach allowed them to pinpoint differences in the level of activity of certain liver genes, referred to as "differential expression."

Why the interest in liver genes?

In hamsters—and humans—the liver both makes and breaks down cholesterol. "Assay results suggest that activity of some liver genes that either produce or use cholesterol resulted in the lower blood cholesterol levels," says Yokoyama. "This study is, to the best of our knowledge, the first published account of cholesterol-lowering effects in laboratory hamsters fed blueberry peels or fiber or polyphenols extracted from those peels."

New Blueberry Powder Placebo: A Boon for Nutrition Research

PEGGY GREB (D2189-1)



Blueberry powder on vanilla yogurt.

Let's say you volunteer for a study of blueberries and your health. You and your fellow volunteers might be handed little packets of a sweet-tasting, purple-blue powder to sprinkle on your breakfast cereal.

You'll know, at the start of the study, that the powder some of you will be given is made of fresh, whole blueberries that have been freeze-dried. Other packets, for the rest of you, will have an imitation—a look-alike powder that serves as a placebo.

Thanks to Agricultural Research Service scientists in Albany, California, there's a new placebo that is the first to capture the look, taste, texture, and aroma of real blueberry powder.

PEGGY GREB (D2187-1)

The placebo is the work of Tara H. McHugh, a food technologist and research leader of the ARS Processed Foods Research Unit, and colleague Donald A. Olson, a support scientist in McHugh's team. Both are with the ARS Western Regional Research Center in Albany.

A few years ago, the Folsom, California-based U.S. Highbush Blueberry Council, which administers marketing and research programs for growers and importers of blueberries, sought McHugh's help in developing a new placebo that would match the Council's own freeze-dried blueberry powder. "Now we can offer the placebo to scientists who are using our blueberry powder in research that we fund," says Leslie Wada, a registered dietitian and research administrator for the Blueberry Council.

For some scientific investigations, a powder may be a better choice than fresh, whole berries. "Using a powder can help eliminate some of the natural variation that can occur in fresh berries from one harvest to the next as well as from region to region," says Wada.

"Though such variation may be minor, the uniformity of a standard powder may provide a more consistent, scientifically sound basis of comparison among results from different research institutions.

"Placebo-controlled studies are the gold standard in human nutrition research. Now there's a superior placebo for pairing with our blueberry powder in this kind of research."

The placebo is already being used in studies with elderly volunteers to determine the effects of blueberries in counteracting age-associated changes in brain function.—By **Marcia Wood,** ARS.*

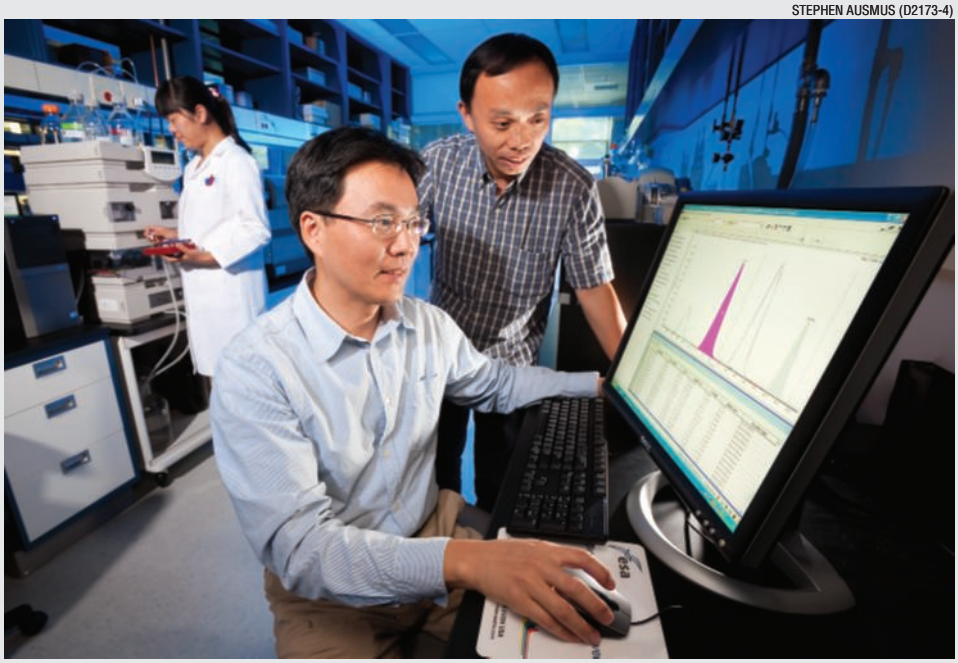
Student intern Bumjeun Kim (left) and food technologist Don Olson prepare the blueberry placebo for packaging.

Not all pieces of the cholesterol puzzle are in place. The researchers don't yet know which berry compound or compounds activated the liver genes, or which parts of the berry have the highest levels of these compounds. Yokoyama's ongoing research may answer those and other questions.

Blueberries Help Mouse Cardio Health, Too

High cholesterol can increase risk of cardiovascular disease—America's number-one killer. At the Arkansas Children's Nutrition Center (ACNC) in Little Rock, Xianli Wu is determining whether compounds in blueberries are involved in reducing risk of atherosclerosis. Wu is a principal investigator at the center, head of its Analytical Laboratory, and a research assistant professor with the University of Arkansas for Medical Sciences—also in Little Rock.

STEPHEN AUSMUS (D2173-4)



At the Arkansas Children's Nutrition Center, Little Rock, Arkansas, left to right, postdoctoral research associate Jie Kang, investigator Xianli Wu, and research assistant Yudong Tong use HPLC-MS to analyze blueberry compounds and the biomarkers related to atheroprotective effects of blueberries.

Atherosclerosis is sometimes described as "hardening of the arteries." It can set the stage for two leading forms of cardiovascular disease—heart attack and stroke.

Atherosclerosis is characterized by unhealthy deposits of fats (lipids) inside blood vessels. These deposits form lesions known as "plaques" and can increase risk of cardiovascular disease.

Wu has chosen, as his research model, laboratory mice that are predisposed to developing these atherosclerotic plaques. Medical researchers worldwide regard the plaques developed in this mouse model as similar to those that can form in human arteries.

In a 2010 issue of the *Journal of Nutrition,* Wu and coinvestigators suggest that, based on their studies in mice, blueberries may play a role in reducing the formation of atherosclerotic plaques.

"Our study provides the first evidence of its kind that blueberries can help prevent atherosclerotic plaques from increasing in size in arteries of laboratory animals," says Wu. Specifically, Wu's team compared the size, or area, of plaques in 30 of the mice. Half of the animals were fed rations that included freeze-dried whole blueberries in the form of a powder. Rations for the other mice didn't contain the berry powder.

The researchers measured the size of plaques in the aorta, the large artery that—in mice and humans—extends from the heart to other, smaller arteries, transporting oxygen-rich blood.

Plaque area, measured at two aortal sites, was 39 and 58 percent less in the blueberry-fed mice than in those not fed the blueberry powder.

Now, Wu's group wants to uncover the mechanisms that played a role in control of plaque size in the research animals. His team's real-time polymerase chain reaction tests and other assays suggest that antioxidant enzymes may be involved.

As their name suggests, those enzymes help counteract oxidative damage caused by molecules known as "free radicals."

The results showed that levels of genes associated with four of these enzymes, and the activity of the enzymes themselves, increased in the blueberry-fed mice.

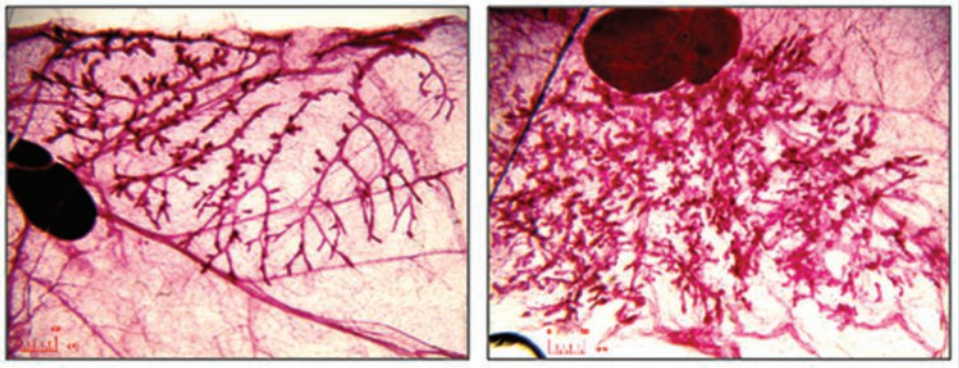
Wu collaborated in the investigation with Little Rock colleagues, including Thomas M. Badger, ACNC director and professor at the University of Arkansas for Medical Sciences, and Shanmugam Nagarajan, a principal investigator at ACNC and associate professor at the university.

"It's already known that oxidative stress can increase atherosclerosis risk," says Wu, "so the beneficial interactions of blueberries with these antioxidant enzymes are of interest to us. Since our center specializes in children's nutrition research, we also want to determine whether blueberry-based interventions early in life could prevent atherosclerosis from developing in later years. If Mom eats blueberries during her pregnancy and feeds blueberries to her child, would that have a protective effect for the child? We don't know, but that's something we'd like to determine."

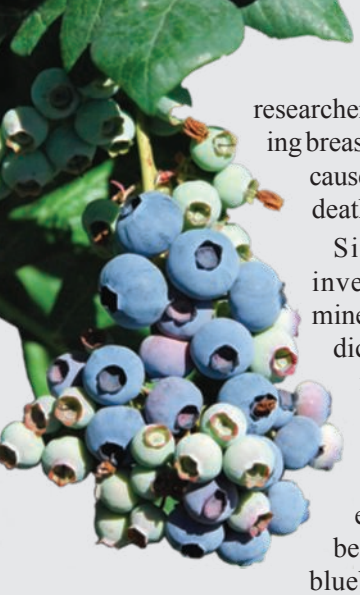
Can Blueberries Fight Breast Cancer?

Mom's nutrition and its effects on baby are also of interest to colleague Rosalia C. M. Simmen, a senior investigator who leads ACNC's Breast Development Laboratory and who is also a professor at the university. Her studies of mammary gland development in laboratory rats may help medical

RENEE TILL (D2209-1)



Female rat pups whose mothers were fed blueberry-enhanced rations had better mammary gland branching (right) than controls (left), whose mothers did not consume blueberry-spiked feed.



researchers who are studying breast cancer, a leading cause of cancer-related deaths in women.

Simmen and co-investigators determined that several indicators of rat mammary gland health were improved in the offspring (pups) of mothers (dams) that had been fed 5-percent blueberry powder in their rations during pregnancy and during the weeks that they nursed their pups. The powder comprised 5 percent of the total weight of the feed.

Simmen's team evaluated several structural indicators of normal mammary gland development, including branching of the gland. There was significantly more branching in the offspring of the 5-percent group than in offspring of dams fed rations containing 2.5-percent or 10-percent blueberry powder.

"Branching occurs when cells specialize or differentiate," says Simmen. "Differentiation is generally preferable to rapid proliferation of undifferentiated cells, which can be a risk factor for breast cancer."

The team also analyzed several biochemical indicators and found, for instance, that the level of a tumor-suppressing protein, PTEN (which stands for "phosphatase and tensin homolog deleted in chromosome 10") was significantly higher in mammary tissues of offspring of dams on the 5-percent regimen. That's a plus, because PTEN is thought to help protect against cancer.

In contrast, *decreases* in PTEN "are associated with development of many kinds of cancers in humans," Simmen explains.

"The 5-percent regimen was sufficient to significantly influence mammary gland health," Simmen points out. "The effect was lost with the higher, 10-percent blueberry rations."

Lab animal studies of blueberries' potential role in preventing breast cancer date back to 2006. But Simmen's investigation, published in *Nutrition Research* in 2009, provides the first evidence, from a lab animal study, of the early influence that the mother's blueberry consumption can have on normal, healthy development of the mammary gland in her offspring.

Simmen collaborated in the research with Xianli Wu; Ronald L. Prior, formerly a chemist and principal investigator with the center; and Ph.D. student Omar Rahal.

The effects noted in the study have not been shown in humans and have not yet been traced to a particular blueberry compound. But if the findings indeed turn out to hold true for humans, they would suggest that "maternal diet and, specifically, fruit consumption, can change the course of breast development in offspring," according to Simmen. "The study provides strong support for the idea that early exposure, even in the womb, to healthy eating may profoundly affect the health of the unborn child. In short, you are what your mother eats."

In Lab Rats, Blueberries Help Build Strong Bones

If you were asked, "What foods build strong bones?" blueberries might not be the first food that comes to mind. But color-imparting polyphenols might turn out to have a powerful effect on formation of strong, healthy bones.

This idea is being explored by Jin-Ran Chen, M.D., and his ACNC colleagues. Chen is a principal investigator and lead scientist in the Skeletal Development Laboratory at the center and is an assistant professor at the university. He specializes in research on how what we eat, during infancy, childhood, and early adulthood affects growth and development of our bones and our risk of developing osteoporosis or other degenerative bone diseases in later years.

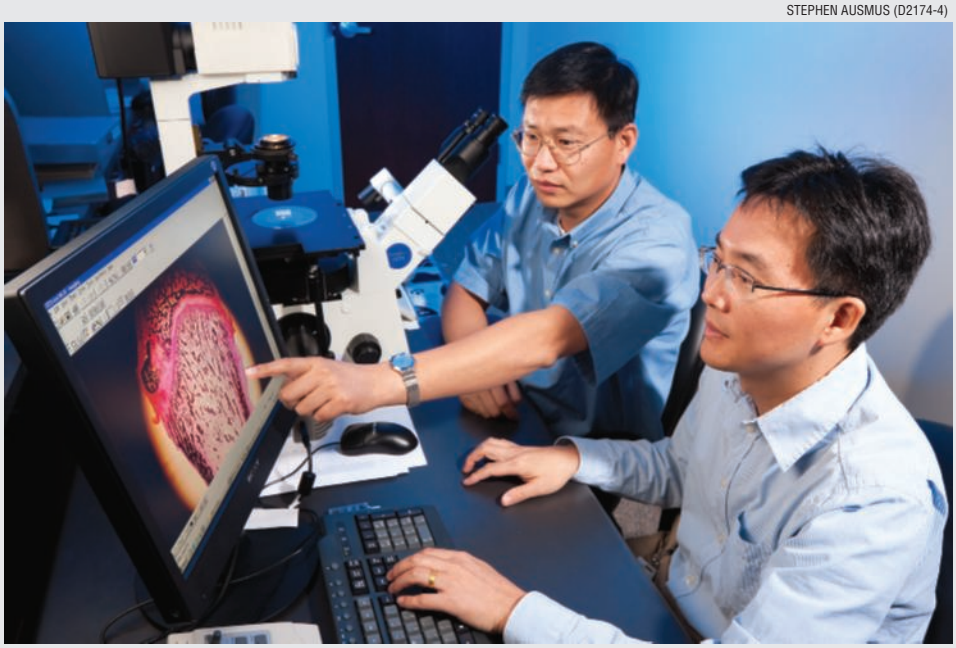
A weakening of bone that can lead to painful deformities, osteoporosis affects an estimated 10 million Americans. Another 34 million are at risk of developing the disease.

Chen's recent studies with young, rapidly growing laboratory rats suggest that blueberries might aid in building strong bones. The work has paved the way for new studies that might reveal whether blueberries could, in the future, be used in treatments to boost development of peak bone mass and to help prevent osteoporosis.

Published in the *Journal of Bone and Mineral Research* in 2010, the investigation showed that animals fed rations that contained 10 percent freeze-dried blueberry powder had significantly more bone mass than their counterparts whose rations were blueberry free.

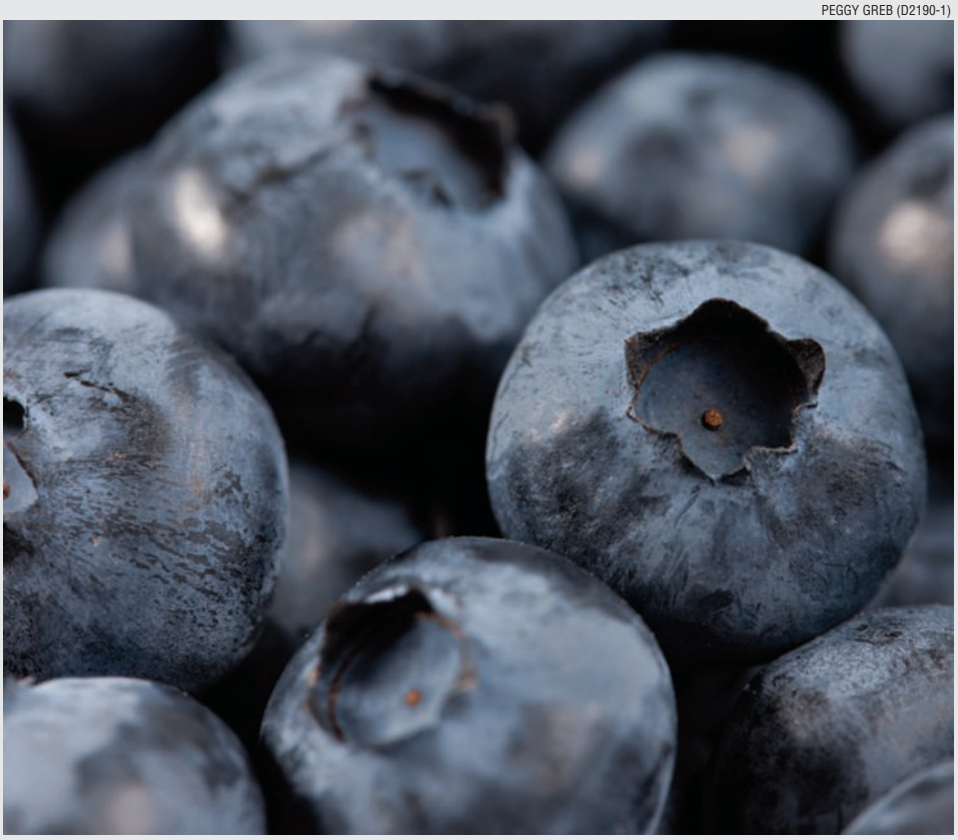
Exploring further, the researchers exposed laboratory cultures of bone-forming cells (osteoblasts) to blood (serum) from the animals. Serum from the blueberry-fed rats was associated with an increase in development of osteoblasts into mature, functional bone cells.

STEPHEN AUSMUS (D2174-4)



At Little Rock, Arkansas, investigators Jin-Ran Chen (left) and Xianli Wu use a fluorescent microscope to view inside a rat bone in studies to evaluate the effects of blueberries on bone function.

PEGGY GREB (D2190-1)

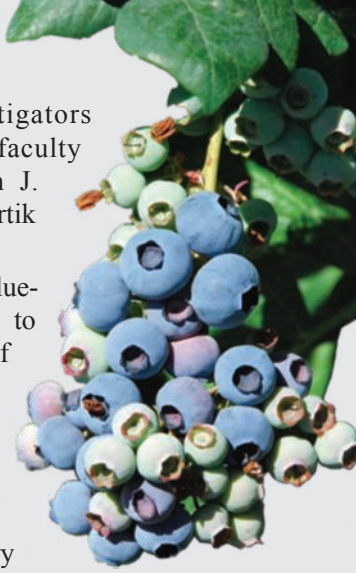


Fresh blueberries.

Serum in the blueberry-fed rats was high in phenolic acids, derived from blueberry polyphenols. The research suggests that the phenolic acids are responsible for the bone-building effects documented by the scientists.

Chen's team has also found a potential mechanism of action, or sequence of steps, by which blueberry-derived phenolic acids stimulate bone building in the rats. Their tests suggest that the pathway involves, for example, two genes, *TCF* and *LEF*, and a protein, beta-catenin. Beta-catenin is responsible for prompting osteoblasts to become mature and functional. *TCF,* or T-cell factor, and *LEF,* or lymphoid-enhancer binding factor, are responsible for promoting synthesis of beta-catenin.

Chen's collaborators in the study included Badger and Wu; and ACNC principal investigators and university faculty members Martin J. J. Ronis and Kartik Shankar.

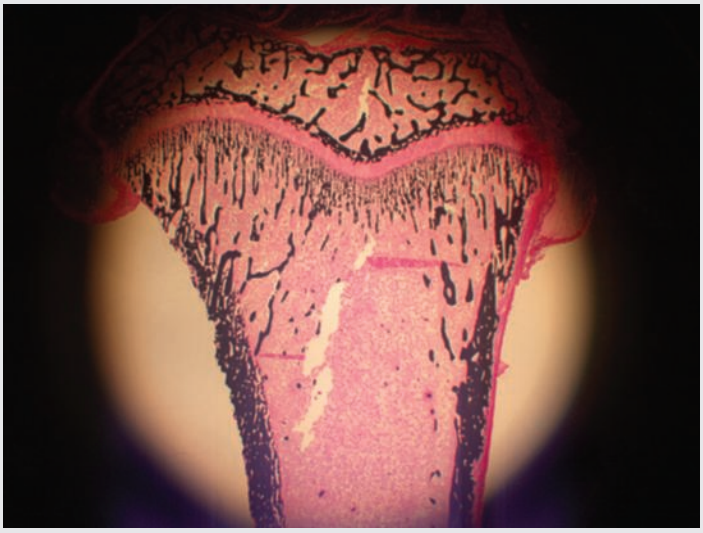


The idea that blueberries may help to reduce our risk of disease, in ways yet unproven, continues to intrigue nutrition researchers across the country and around the world. As this array of lab-animal and cell-culture studies demonstrates, ARS scientists are no exception. Researchers, and blueberry's many fans everywhere, await the outcome of follow-up studies—with volunteers—that will clearly define the blueberry's role in improving our health.—By **Marcia Wood,** ARS.

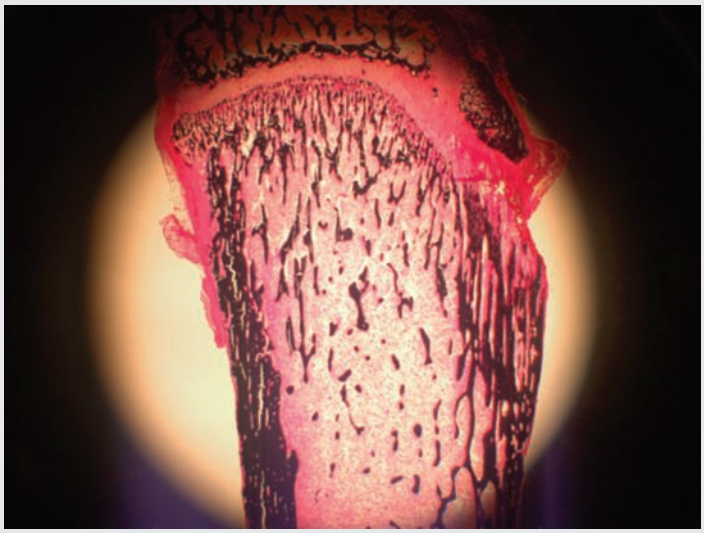
This research supports the USDA priority of improving children's nutrition and health and is part of Human Nutrition (#107) and Quality and Utilization of Agricultural Products (#306), two ARS national programs described at www.nps.ars.usda.gov.

To reach scientists mentioned in this article, contact Marcia Wood, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1662, marcia.wood@ars.usda.gov. ✻

Cross-section of leg bone from a control-fed rat (left) and a blueberry-fed rat (right) as viewed with fluorescent microscopy. The black-stained areas are newly formed bone, and the pink and white areas are bone marrow.



JIN-RAN CHEN (D2175-1)



JIN-RAN CHEN (D2176-1)

Blueberry Growing Comes to the National Agricultural Library

The path to domestication for most of our crops is lost in the mists of agriculture's 10,000-year history. Blueberries are the exception.

Until 1911, blueberries were picked from the wild, or bushes were dug from the wild that might or might not survive when planted elsewhere. But true domestication—reproduction at the will of a grower and breeding to improve desirable traits—was beyond reach. This makes blueberries among the most recently domesticated crops and one of the few that originated in North America, although they are now grown all over the world.

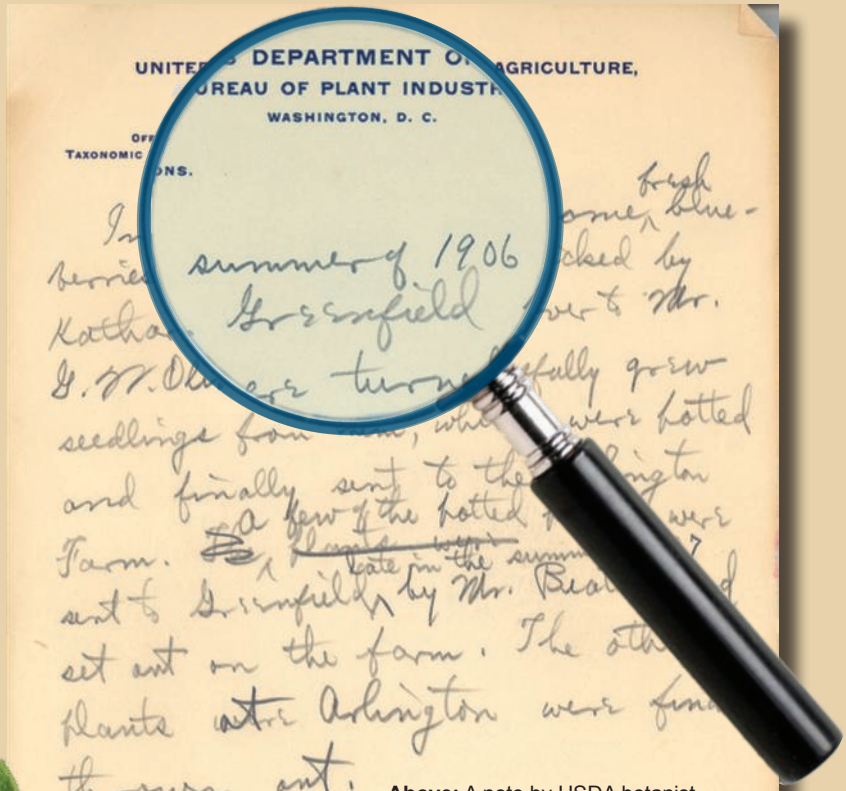
It was U.S. Department of Agriculture botanist Frederick Coville who set the stage for commercial production by solving the first great mystery of why blueberries could not be cultivated well when he showed, in 1910, that the plants must be grown in moist, very acidic soil. Soon after, he made the first successful crosses designed to improve important traits, such as berry size and flavor. The blueberry was tamed.

Now Coville's handwritten research notes have been added to the Rare and Special Collections at the National Agricultural Library (NAL), in Beltsville, Maryland. The material includes complete descriptions of blueberry plant parentage and field note data as well as daily, penciled entries of his work. There are also more than 1,000 black-and-white photographs of blueberries and more than 100 glass-plate negatives and positives from USDA blueberry research.

The records provide a fascinating look at the USDA research effort that took blueberries from a crop picked from the wild and sold for 14 cents a quart in 1912 to a commercially grown crop worth more than $530 million today.

Coville's notes provide insight into how monumental a task it was to begin transforming blueberries into a domesticated crop. In his June 1, 1907, entry, he quotes a statement that the renowned botanist Liberty Hyde Bailey "once got a bushel of blueberries…and failed to make a single seed grow."

(D2192-6)



(D2192-1)

Above: A note by USDA botanist Frederick Coville describing his pioneering research on domesticating blueberries.

Left: In 1908, Coville chose this wild highbush plant with berries of superior size and flavor as one of the foundation parents of his breeding program. He named it "Brooks" after Fred Brooks, a neighbor on whose New Hampshire land the bush was growing.

(D2192-3)

This botanical illustration documents Stanley, a mid- to late-season blueberry with dessert-quality berries. Coville named this plant after his son on whose plantation in New Lisbon, New Jersey, the variety was first shown to produce "good yields of berries of large size."

MARK LONGSTROTH, MICHIGAN STATE UNIVERSITY (D2193-1)

Bluecrop, released by Coville in 1941, is easy to grow and easy to eat. It remains one of the country's most popular mid- to late-season varieties.

Paging through his observations clearly shows the evolution of his how-to-grow blueberry studies. His records begin with comparing plant growth in alkaline, neutral, and acid soil. By 1908, Coville had pretty much dropped alkaline soil from testing. In growing studies done at Arlington Farm (now the south parking lot of the Pentagon), Coville wrote, "Peat was procured yesterday from underneath some *Kalmia* (mountain laurel) bushes on the Virginia side of the Potomac opposite Plummer's Island." He had remarkable success with this very-low-pH soil. While most plants prefer soil at the neutral pH 7, blueberries only thrive at pH 4.5 to 4.8. It was a novel concept at the time and one that Coville, in his later years, said he considered his greatest discovery.

In 1910, Coville published Experiments in Blueberry Culture (USDA Bulletin 193), with his directions for growing blueberries. He expanded these directions in a number of revisions over the years.

Then Coville went on to solve the second mystery of why blueberries could not be bred as easily as most other plants when he discovered that blueberries are not self-fertile and that they require cross-pollination. He also recognized that each parent must have an equal number of chromosomes, something not necessarily the norm in a genus as variable as *Vaccinium*.

Coville was also the first to determine how to propagate blueberries, allowing production of thousands of identical plants once a good hybrid was bred. This was critical to the large-scale production of consistent, uniform blueberry fruit. Prior to his research, it was believed that blueberries couldn't be propagated.

In 1911 came his landmark first successful crosses between two wild blueberries—one highbush and one lowbush—that had been selected for their superior qualities from a pasture in Greenfield, New Hampshire. These were named Brooks and Russell. The crosses he made in 1911 and 1913 resulted in 3,000 hybrids. Another cross of Brooks with a wild blueberry named Sooy in 1912 resulted in another 3,000 seedlings.

"From these, over 1,000 seedlings were actually transplanted [to the field] and as many more might easily have been utilized," was the assessment Coville recorded.

These crosses led to the release of the first hybrid, aptly named Pioneer (Brooks x Sooy), in 1920, followed by the release of Cabot and Katherine.

Much of Coville's original wild breeding stock came from his partnership with Elizabeth White of Whitesbog, New Jersey. She acquired high-quality bushes by recruiting native blueberry pickers to locate and tag desirable large-fruited bushes for use as parental stock, and then she personally went out and brought them back to Whitesbog and made them available to Coville.

The handwritten notes and botanical illustrations in this story are part of the Rare and Special Collections at the National Agricultural Library.

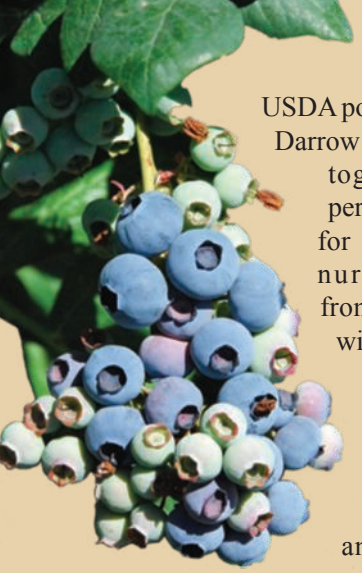
Coville's crosses continued to be released for many years after his death in 1937 and included Bluecrop, Blueray, and Earliblue, varieties still popular today with gardeners and commercial growers. By 1942, of the 18 blueberry varieties offered by eastern growers, 14 were the result of Coville's selection or breeding. His varieties remain part of the pedigree of most varieties grown today.

The USDA research program Coville founded in New Jersey continues today, carrying out critical research to protect and expand the U.S. blueberry crop. Consumer demand continues to increase at a rapid pace, especially since the recognition of blueberry's health benefits.

The NAL's Rare and Special Collections hopes to raise funding to scan the Coville records along with other blueberry material it has recently received so that the records can be available via the Internet. Some of the additional material includes blueberry virus data from 1943 and 1944,

Catawba was the second albino variety that Coville named. It was bred from the same parents as Redskin (shown on next page), but its red coloring was paler, "more like the color of the Catawba grape," hence the name.

(D2192-2)

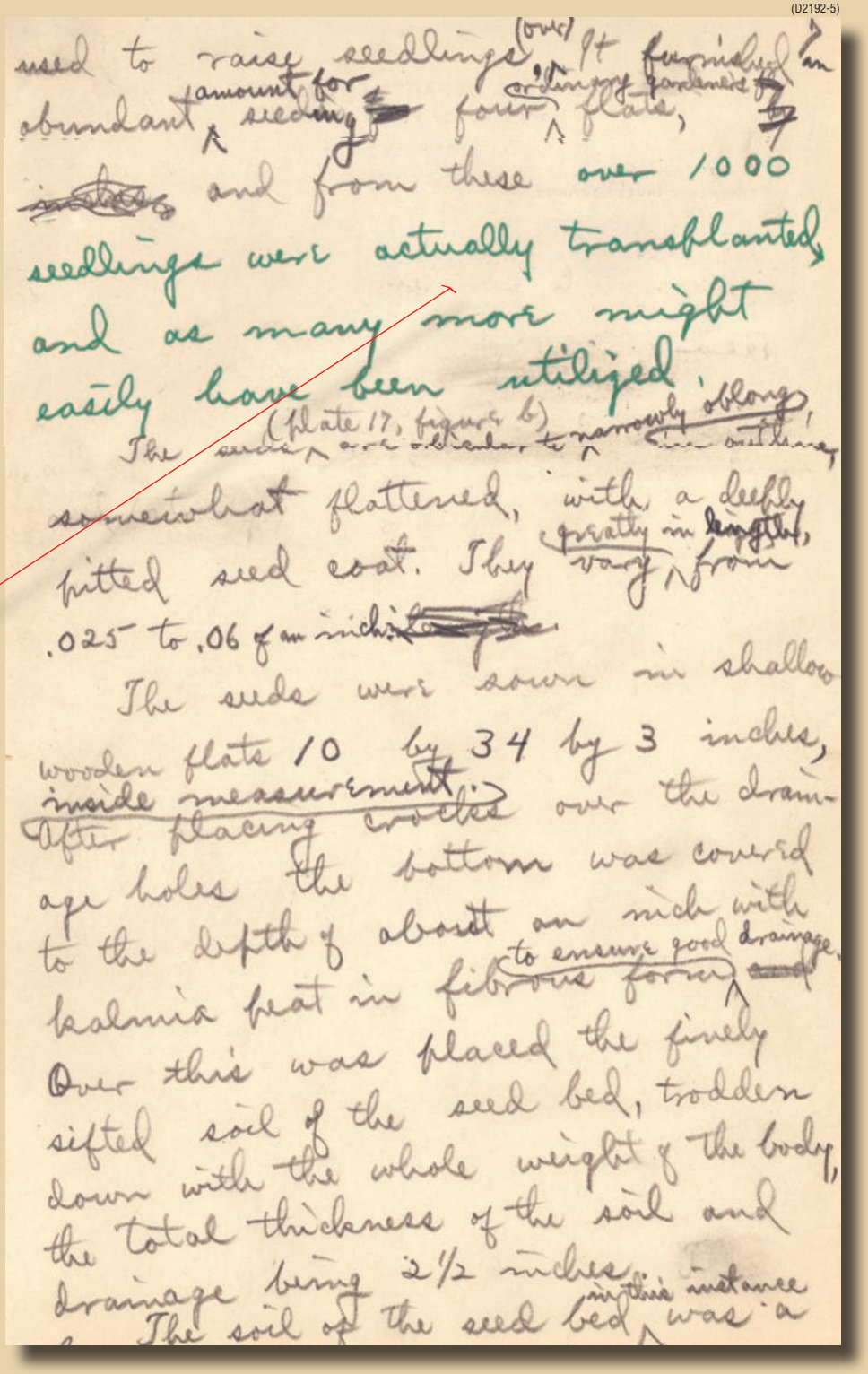


USDA pomologist George Darrow's notes and photographs on rest-period requirements for blueberries, and nursery catalogs from 1943 to 1970 with sources listed for a number of cultivars.

"Coville's research notes give historians and scientists an opportunity to follow both the thinking and progress of one of the foremost breeders in the world as he developed the first blueberry cultivars," says Robert Griesbach, a plant geneticist who is currently deputy assistant administrator for ARS's Office of Technology Transfer. "These notes are quite detailed, and besides the observations on genetic advances, they provide insights into the original breeding approaches taken for disease control, production, and the development of the new industry."—By **J. Kim Kaplan,** ARS.

For more information on this blueberry research collection, contact Sara B. Lee, USDA-ARS National Agricultural Library, Rare and Special Collections, 10301 Baltimore Ave., Beltsville, MD 20705; (301) 504-5876, sara.lee@ars.usda.gov.

(D2192-5)


used to raise seedlings (over) 9t furnished an abundant amount for seeding four flats, and from these over 1000 seedlings were actually transplanted, and as many more might easily have been utilized.

(Plate 17, figure b)

The seeds are oblong, narrowly oblong, somewhat flattened, with a deeply pitted seed coat. They vary greatly in length, from .025 to .06 of an inch.

The seeds were sown in shallow wooden flats 10 by 34 by 3 inches, inside measurement. After placing crocks over the drainage holes the bottom was covered to the depth of about an inch with kalmia peat in fibrous form to ensure good drainage. Over this was placed the finely sifted soil of the seed bed, trodden down with the whole weight of the body, the total thickness of the soil and drainage being 2½ inches. In this instance the soil of the seed bed was a

...over 1000 seedlings were actually transplanted, and as many more might easily have been utilized.

(D2192-4)

Redskin blueberry is an albino, where the berries become red on the side exposed to the sun. Coville released the variety as a horticultural curiosity that might be desirable for the home garden.

STEPHEN AUSMUS (D930-2)

With Feedlot Manure, It Pay$ To Be Precise

Technician Todd Boman collects soil electrical conductivity readings as he drives through a vegetative treatment area. These values are used to generate maps illustrating nutrient distribution in the vegetative treatment area.

The same precision farming techniques that work with crops can work with manure management on cattle feedlots.

Agricultural engineers Roger Eigenberg and Bryan Woodbury and colleagues at the Agricultural Research Service Environmental Management Research Unit at the Roman L. Hruska U.S. Meat Animal Research Center in Clay Center, Nebraska, map the distribution of manure on the surface of feedlots and the flow of liquid manure in rain runoff.

This research could lead to both precision harvesting of manure and precision application of manure to crop fields, while controlling nutrient losses and gas emissions.

The scientists map manure distribution by towing a GPS-equipped sensor on a trailer pulled by an all-terrain vehicle over feedlot pens and cropland at about 6 miles per hour. The sensor estimates the amount and quality of manure in various places on the feedlot surface by measuring the manure's ability to conduct electricity.

Manure contains about 5 to 10 percent salt by dry weight, which comes from salt supplements in cattle feed. Salt in solution is an excellent conductor of electricity; therefore, dissolved salt in manure and manure-amended soils increases their electrical conductivity.

Eigenberg, Woodbury, and colleagues used a computer program called "ESAP," for Electrical Conductivity Spatial Analysis Program, to choose spots on the feedlots and a nearby hayfield to sample soils, rather than sample randomly. The U.S. Salinity Laboratory in Riverside, California, developed the program. Eigenberg and colleagues used the program to associate high soil conductivity levels with manure solids and with the chloride in the salts found in manure.

In more recent work, Woodbury, Eigenberg, and colleagues found that they could also use the program to correlate high soil conductivity with nitrogen, phosphorus, and the volatile fatty acids associated with manure odors.

In the earlier study, Eigenberg and Woodbury compared two experimental beef cattle feedlot pens at Clay Center—each having a very different, but common, management style—and found the correlations worked well in estimating the quantity and quality of manure solids on the feedlot floor in both pens.

The soil conductivity and modeling techniques could be used to help feedlot operators recover valuable byproducts from the feedlot. For example, manure with higher nitrogen and phosphorus content could be harvested for use as fertilizer. This would have the added benefit of reducing nutrient losses, and it could identify areas prone to odors so they could be treated with improved drainage or, possibly, with antimicrobial compounds.

Eigenberg and Woodbury also mapped a vegetative treatment area downslope of the Clay Center feedlot. Rain runoff from eight pens flows into a settling basin at the base of the feedlot. After the solids settle, the liquid manure flows through tubes onto a hayfield designed to capture and use manure nutrients.

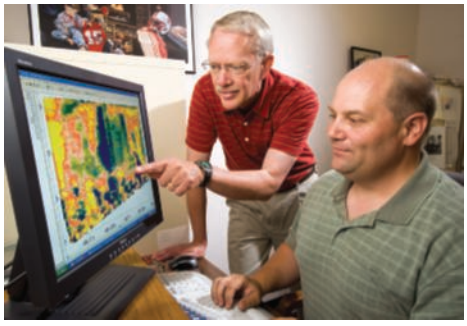
The scientists could tell from the soil conductivity maps that the liquid manure was being unequally distributed. With this information, they made adjustments to the flow tubes, resulting in a more uniform distribution of the runoff and improved effectiveness of the treatment area.

"The idea is to have more of the nitrogen and phosphorus fertilizing hay than being lost to the environment," Eigenberg says. "This work will help improve techniques for handling manure on both feedlots and crop fields. Manure can be harvested for the greatest value possible, whether for energy or fertilizer, and used more efficiently, which should greatly reduce pollution and odors."—By **Don Comis,** ARS.

This research is part of Agricultural and Industrial Byproducts (#214), an ARS national program described at www.nps.ars.usda.gov.

Roger A. Eigenberg and Bryan L. Woodbury are with the U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, NE 68933; (402) 762-4272 (Eigenberg), (402) 762-4275 [Woodbury], roger.eigenberg@ars.usda.gov, bryan.woodbury@ars.usda.gov.

Agricultural engineers Roger Eigenberg (left) and Bryan Woodbury evaluate a soil electrical conductivity map of a vegetative treatment area.



STEPHEN AUSMUS (D929-1)

Putting Dairy Cows Out to Pasture
An Environmental Plus

Every year, a hefty dairy cow tucked away in a snug barn produces more than 20,000 pounds of milk, along with an impressive amount of manure and an array of gases. New modeling work by an Agricultural Research Service team in University Park, Pennsylvania, suggests that a dairy cow living year-round in the great outdoors may leave a markedly smaller ecological hoofprint than her more sheltered sisters.

Agricultural engineer Al Rotz led a team of scientists at the ARS Pasture Systems and Watershed Management Research Unit through a modeling study that evaluated how different management systems on a typical 250-acre Pennsylvania dairy farm would affect the environment. "If we try to reduce one environmental factor in this complex production system, we can end up increasing others," Rotz says. "So there's a real need to look at all the environmental aspects together."

Several other ARS University Park scientists collaborated on the project, including animal scientist Kathy Soder; plant physiologist Howard Skinner; soil scientists Curtis Dell, Peter Kleinman, and John Schmidt; and research leader Ray Bryant. For its study, the team used the Integrated Farm System Model, a computer program developed at University Park that simulates the major biological and physical processes and interactions on a crop, beef, or dairy farm.

The scientists collected a range of field data on grazing systems and manure management and their effects on nutrient loss to the environment. Then they input this field data into their farm model to evaluate the environmental dynamics of four different dairy farms in all types of weather over 25 years.

Left to right, Pennsylvania State University agricultural engineer Michael Hile, ARS agricultural engineer Al Rotz, and ARS research associate Felipe Montes use a dynamic flux chamber to measure the emission rates of gaseous compounds from manure on a dairy barn floor.

STEPHEN AUSMUS (D2206-2)

Livestock Logistics

One simulation modeled production on a confinement farm that contained a herd of 85 large-framed Holsteins, each producing 22,000 pounds of milk every year, and 76 replacement heifers.

Another modeled production on a confinement farm with a herd of 100 moderate-framed Holsteins and 80 replacement heifers. Each cow in this system produced 18,500 pounds of milk each year.

A third type of farm in the model also had 100 Holsteins with average frame size and 80 replacement heifers. But in this system, the cows were able to graze for up to 7 months every year. Each cow in this system also produced 18,500 pounds of milk every year.

The last farm in the model had a herd of 130 small-framed Holstein/Jersey crossbred cows and 95 replacement heifers. This herd was maintained outdoors all year, calved in the spring when forage availability was at its peak, and was managed with rotational grazing during the summer. Cows in this system produced almost 9,000 fewer pounds of milk per cow each year than cows in the confinement system with the highest production.

All four systems were set to produce essentially the same amount of milk—adjusted for fat and protein—on the same land. Standardizing the total milk production across the four production systems allowed better comparison of the various environmental impacts across systems.

The model generated estimates for ammonia emissions from manure, soil denitrification rates, nitrate-leaching losses, soil erosion, and phosphorus losses from field runoff. Estimates for emissions of carbon

dioxide, methane, and nitrous oxide from both primary production and secondary production of pesticides, fuels, electricity, and other resources were also considered.

A Breath of Fresh Air

The researchers found that total emissions for the greenhouse gases methane, nitrous oxide, and carbon dioxide were 8 percent lower in year-round outdoor production systems than in the high-production confinement systems. The biggest payoff? Keeping dairy cows outdoors all year lowered ammonia emissions by about 30 percent.

"Air quality is a big environmental problem facing dairy producers today, and it's difficult to control," Rotz says. "Getting cows out of barns is a key factor in mitigating ammonia emissions, because it reduces the amount of manure that needs to be handled and stored before it's used for fertilizer. This is especially important during the summer, when emissions from stored manure increase."

Keeping cows outdoors also helped reduce fuel use and the resulting carbon dioxide emissions from farm equipment, because producers didn't need to plant and harvest as much feed for their livestock. Average net farm greenhouse gas emissions dropped about 10 percent by keeping the herd outdoors year-round. When fields formerly used for feed crops were converted to perennial grasslands for grazing, carbon sequestration levels climbed from zero to as high as 3,400 pounds per acre every year.

"The carbon sequestration benefits really add up," Rotz says. "When farmland is transitioned from rotated crops to perennial grassland, you can build up lots of carbon in the soil and substantially reduce your carbon footprint for 20 to 30 years."

The scientists also calculated the carbon footprint left behind by cows in each of the four management systems for every pound of milk produced. They found that a well-managed dairy herd kept outdoors year-round left a carbon footprint 6 percent smaller than that of a high-production dairy herd kept in barns.

STEPHEN AUSMUS (D2207-1)

Plant physiologist Howard Skinner (left) and technician Steve LaMar check sensors and download carbon dioxide flux data from an eddy covariance system on a pasture at Penn State, Haller research farm. The data is used to monitor carbon sequestration on pastures and contribute to whole farm carbon footprint modeling.

Although the confined cow produced 22,000 pounds of milk every year and the foraging cow produced only 13,000 pounds, the total amount of milk protein and fat produced on the two farms was essentially the same, because the foraging cows produced milk with more fat and protein. In addition, the same amount of land supported a larger number of the small-framed Holstein/Jersey crossbred cows.

Water Quality Also Wins

What's good for the air is also good for water. When high-producing dairy cows were kept in barns year round, the associated sediment erosion from growing corn and alfalfa for feed averaged 2,500 pounds per acre. But when cows foraged on perennial grasslands—their diets supplemented as needed with purchased feed—sediment erosion dropped 87 percent to an average of 330 pounds per acre. Runoff of phosphorus, a major pollutant in the Chesapeake Bay Watershed, dropped from around 57 pounds per acre to 44 pounds per acre.

"The model results are supported by years of field work, so they're in line with what we expected," Rotz says. "Now we'll use this model to evaluate other mitigation strategies for both grazing and confinement livestock-farming systems."—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.

To reach scientists mentioned in this article, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628, ann.perry@ars.usda.gov.

Solving Challenges in Sugarcane Factories and Refineries

Award-Winning Factory and Pilot Plant Studies Provide Solutions

PEGGY GREB (D2197-1)

In the new sugar-processing pilot plant at SRRC, chemist Gillian Eggleston (center) works with chemical engineer Brett Andrzejewski (right) and physical science technician Eldwin St. Cyr (left) to process sugarcane.

Very high purity. Very low color.

These terms aren't describing the latest diamonds from Tiffany's. They describe the ideal qualities of sugar crystals after industrial processing.

In the field, the cane is collected by combine harvesters that chop up, or "billet," the cane into pieces of about 9 inches in length. Those pieces are shredded at the factory. Juice is then extracted and must be clarified, evaporated, crystallized, and centrifuged, resulting in brownish-yellow crystals called "raw sugar" and molasses. That nonfood-grade raw sugar is then sent to a refinery where it is further melted, clarified, and crystallized into the white sugar found in supermarkets.

The nemesis of these sugar crystals is "trash"—impurities such as leaves and tops and muddy soil that piggyback on sugarcane from the field into the factory. These impurities make processing and clarifying cane juice more difficult.

At the ARS Southern Regional Research Center (SRRC) in New Orleans, Louisiana, chemist Gillian Eggleston has been studying sugarcane that comes into factories containing too much trash. When "trashy" cane enters a factory, processing problems occur that can hurt the bottom line. Eggleston is in the SRRC Commodity Utilization Research Unit.

Traditionally, trash amount has been controlled by burning some sugarcane in the field. But environmental concerns have led to a shift away from burning cane in open fields, and that means more trash on the green cane coming into the factory.

Eggleston has now shed light on the effect of processing green, versus burnt, cane. She traveled to South Africa for 3 months in 2008 and there conducted two large factory and pilot plant studies.

In her studies, she processed burnt whole-stalk cane and burnt and unburnt (trashy) billeted cane to assess the quantity and quality of sugar produced from each of these materials—and the effect of trash on the process.

"We separated the brown and green leaves, growing-point region, or top stalk, and the rest of the stalk and weighed each of these tissues just before they went into the factory," says Eggleston. "And then we could correlate that data with the results we got."

(D2200-1)

During a large sugarcane factory trash study in 2008, Gillian Eggleston (left) collects green sugarcane billets from a storage pile at the Noodsberg sugarcane factory in the KwaZulu-Natal Midlands area of South Africa.

Her study showed dramatic effects of harvesting green and burnt billets of cane compared to burnt, whole-stalk cane. "Based on samples produced across the pilot plant that simulated all factory processes, green cane detrimentally affected purity, sugars, ash, and color as well as physical properties such as clarification performance," says Eggleston. "The data showed us, for the first time, that undesirable color in factory sugar is actually coming from the green leaves in the growing-point region, which occurs at the top part of the stalk."

New Approach to Lowering Color

Traditionally, several processes have been used in factories or refineries to lower or remove color—but they are all expensive. Eggleston estimates, from her studies, that for every 1-percent increase in trash levels, there is an increase of about 50 international color units (ICU) for raw sugar and 25 ICU for refinery sugar. She also found that for every 1-percent increase in trash, there is about a one-fifth-percent drop in recoverable crystals. That translates into a $96 million loss per year to the U.S. sugarcane industry.

Her work has led to a recommendation to U.S. sugarcane growers and processors that even a small reduction—such as less than 10 percent—in total trash levels processed at the factory could be more efficient and cost-effective than other factory color-removal processes.

Eggleston won the George and Eleanor Meade Best Paper Award from Sugar Industry Technologists, Inc., (SIT) for her 2009 paper "Factory Trials To Determine How Trash Impacts Downstream Processing," presented at its annual international meeting. This work was also published in the *Proceedings of the South African Sugar Technologists' Association* and won the association's 2009 Talbot-Crosbie award for impact on the industry and relevance of the research.

After returning from South Africa, Eggleston spent 2 years building a sugar-processing pilot plant at SRRC. There, a multitude of further experiments can be conducted to study U.S. sugarcane varieties.

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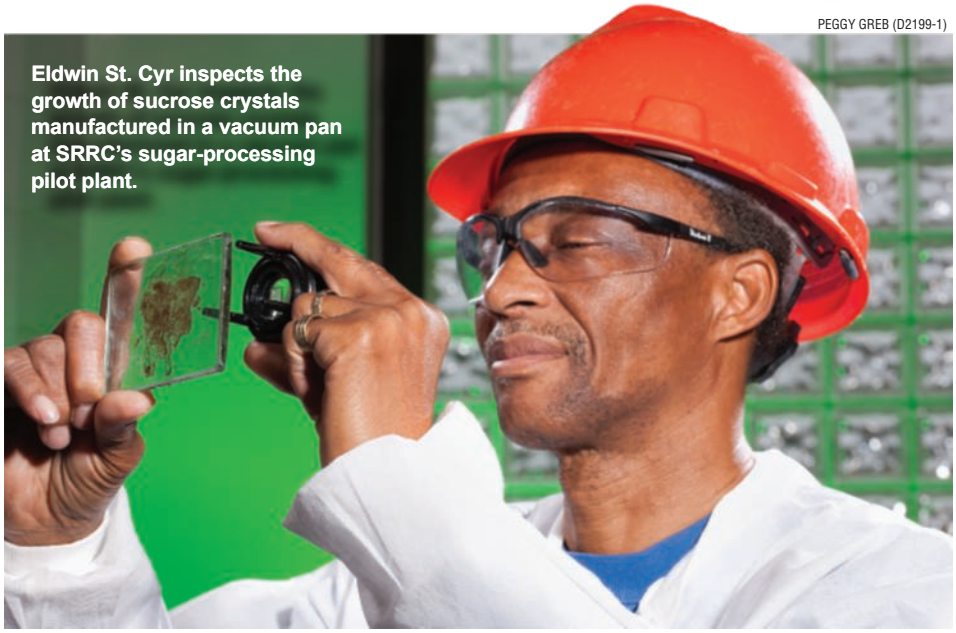

Eldwin St. Cyr inspects the growth of sucrose crystals manufactured in a vacuum pan at SRRC's sugar-processing pilot plant.

Controlling Starch, Controlling Amylase

Another problem associated with the increase in processing green, unburnt cane is increased starch levels in processed raw sugars and products made with those sugars. Use of new U.S. sugarcane varieties is also associated with increases in starch. Now, Eggleston has looked closely at the causes of excess starch in raw and refined sugars, molasses, and food products.

In the United States, an enzyme called "amylase" is added during sugar factory processing to break down long chains of unwanted starch. Eggleston's research alerted factory processors and refiners to the problem of unwanted carryover amylase activity in molasses and raw sugar if high-temperature commercial amylases were applied in the factory.

"Unless the process of applying factory amylase was improved, starch content in raw sugar would continue to rise," says Eggleston.

Trials were conducted in three Louisiana-based factories using an amylase that was intermediate-temperature (IT) stable. Eggleston used diluted solutions of amylase to improve contact between the amylase and starch. "When added to factory tanks, the solutions break starch down into smaller, more manageable molecules," she says.

One of the solutions she tested contained IT-stable amylase diluted threefold in water at the factory. When this solution was added at a dose of 2 parts per million (ppm) per ton of cane juice, starch breakdown was about 32 percent. When the dose was raised to 5 ppm per ton of cane juice, starch breakdown increased to 42 percent. Adding the amylase to the next-to-the-last evaporator—instead of the last evaporator as is traditional—improved starch breakdown even more. Another plus: Using diluted solutions is more cost-effective than using undiluted amylase.

Eggleston won SIT's Frank Chapman Memorial Award for Best Poster Presentation for her work on optimizing amylase applications in raw sugar manufacture that directly concern refiners. A two-part 2008 paper on the work appears in the *International Sugar Journal*. Her recommendation that starch buildup can be better controlled or prevented by applying IT-stable amylase is now being followed by several factories in Louisiana.—By **Rosalie Marion Bliss,** ARS.

This research supports the USDA priority of promoting international food security and 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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Software Helps Farmers and Ranchers Spot Critical Changes in Crop Growth Stages

Greg McMaster has built a computer program, PhenologyMMS (Modular Modeling System), that predicts the timing of plant growth stages so that Central Great Plains farmers and ranchers can know how their crop is progressing and when to apply pesticides, fertilizers, and water. PhenologyMMS also helps them time other management tasks. McMaster developed this decision-support tool after answering numerous calls from farmers and ranchers who wondered when their crop would be at the right stage to spray as required by the pesticide label.

McMaster is an agronomist at the Agricultural Research Service's (ARS) Agricultural Systems Research Unit in Fort Collins, Colorado.

The pesticide label gives the scientific name of the growth stage, but no other hints. McMaster's program gives common names to go with the scientific names and tells growers how to identify the stages and when to expect them, based on weather reports and soil moisture.

To find the right timing, farmers answer questions such as, "What is your planting date?" and "How wet was your soil at planting time?" To answer this question, farmers choose one of these descriptions of soil moisture: "optimum," "medium," "dry," or "planted in dust." The last step is identifying the nearest weather station to access weather data to run a simplified model of growth for each crop chosen. The driving force of the program is cumulative temperature.

The program then simulates crop growth stages for the entire growing season, giving farmers a good idea of when each stage should occur.

McMaster says the program is unique because it covers many crops. Most such programs cover only one crop. "This program includes corn, wheat, barley, sorghum, dry beans, sunflowers, and several millet varieties and is continually being expanded," McMaster says.

The program can be used independently or inserted into existing crop-growth models. It can be downloaded at tinyurl.com/PhenologyMMS.—By **Don Comis,** ARS.

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Market Lighting Affects Nutrients

Many people reach toward the back of the fresh-produce shelf to find the freshest salad greens with the latest expiration dates. But a new study led by Agricultural Research Service scientists may prompt consumers to instead look for packages that receive the greatest exposure to light—usually those found closest to the front.

The study was led by postharvest plant physiologist Gene Lester while in ARS's Crop Quality and Fruit Insects Research Unit, in Weslaco, Texas. Lester and colleagues Donald Makus and Mark Hodges found that spinach leaves exposed to continuous light during storage were, overall, more nutritionally dense than leaves exposed to continuous dark. Lester is now with the USDA-ARS Food Quality Laboratory in Beltsville, Maryland.

For the study, the researchers exposed spinach leaves to light similar to the 24-hour artificial fluorescent light received by spinach in packages located at the front of the display case. A second group was enclosed in two-layer-thick brown grocery-bag paper to represent the "dark treatment."

Both experimental groups were housed in market-type, light-transmissible polymer tubs with snap-tight lids and were kept in walk-in storage chambers at 4°C—the same temperature at which markets currently display packaged spinach. The light reaction of photosynthesis is not temperature dependent and can occur at 4°C in the right type of light.

The researchers found that the continuous light affected the leaves' photosynthetic system—resulting in a significant increase in levels of carotenoids and vitamins C, E, K, and B9, or folate.

While the simulated retail light conditions actually helped the stored leaves gain in content of several human-healthy vitamins, some wilting occurred after 3 days of storage in flat-leaf but not crinkled-leaf types.

Continuous light exposure during retail display combined with specific cultivar selection (crinkled-leaf types) and leaf maturity (baby-leafed size) appears to be the strategy for preserving and enhancing the concentration of spinach-derived human-health bioactive compounds.

Results from this work were published in the *Journal of Agricultural and Food Chemistry.*—By **Rosalie Marion Bliss,** ARS.

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

Locations Featured in This Magazine Issue

Corvallis, Oregon
3 research units ■ 152 employees

Western Regional Research Center, Albany, California
8 research units ■ 250 employees

Fort Collins, Colorado
5 research units ■ 143 employees

Kika de la Garza Subtropical Agricultural Research Center, Weslaco, Texas
4 research units ■ 113 employees

Red River Valley Agricultural Research Center, Fargo, North Dakota
6 research units ■ 150 employees

Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska
6 research units ■ 120 employees

Arkansas Children's Nutrition Center, Little Rock, Arkansas
9 research units ■ 67 employees
(1 ARS employee, 66 university employees)

Oxford, Mississippi
3 research units ■ 102 employees

Thad Cochran Southern Horticulture Laboratory, Poplarville, Mississippi
1 research unit ■ 41 employees

Southern Regional Research Center, New Orleans, Louisiana
7 research units ■ 205 employees

Pasture Systems and Watershed Management Research Unit, University Park, Pennsylvania
1 research unit ■ 40 employees

Henry A. Wallace Beltsville Agricultural Research Center, Beltsville, Maryland
30 research units ■ 953 employees

USDA Jean Mayer Human Nutrition Research Center on Aging, Boston, Massachusetts
20 research units ■ 281 employees
(9 ARS employees, 272 university employees)

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

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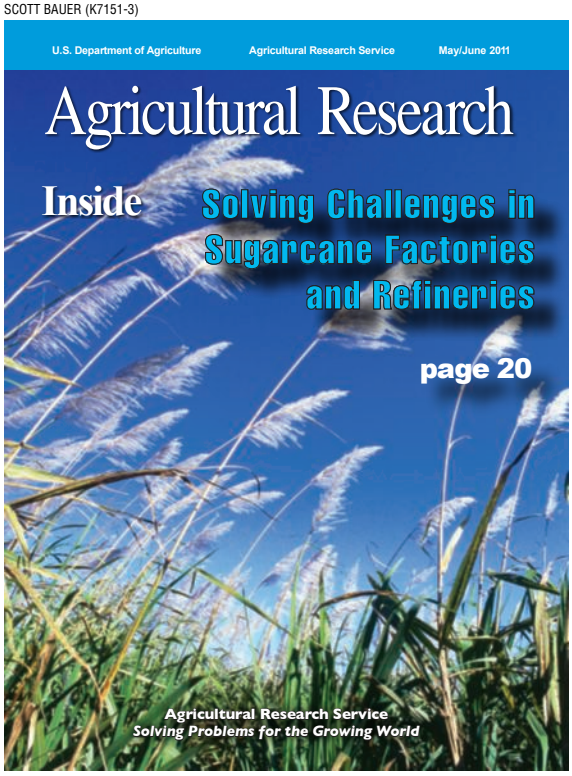

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