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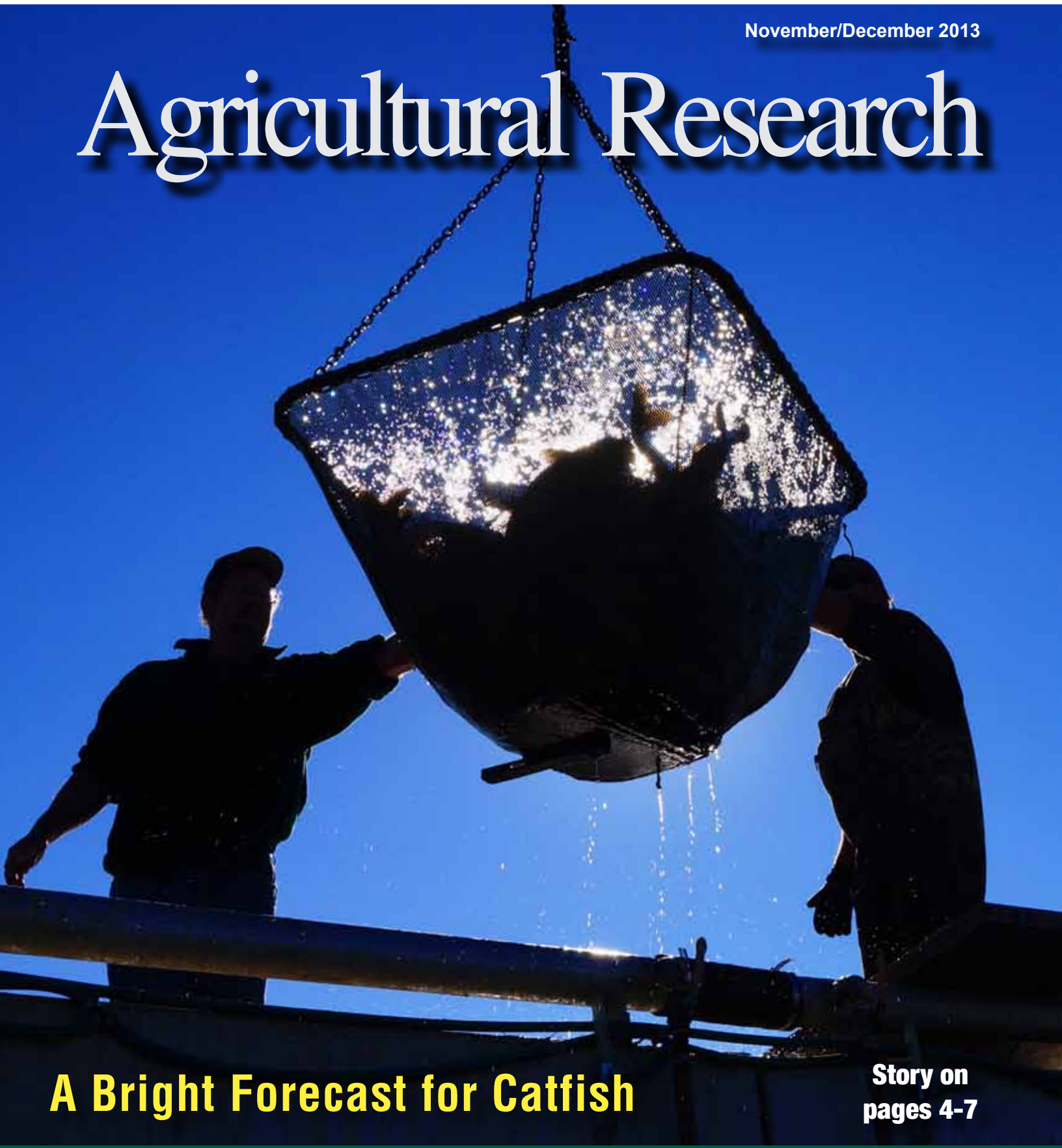

A Bright Forecast for Catfish

Story on pages 4-7

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

FORUM

The Sum Is Greater Than the Parts

Consumption of fish and seafood is increasing, and half of the seafood produced worldwide comes from aquaculture. Catfish production is the largest sector of aquaculture in the United States, and the Agricultural Research Service is working on new advances as well as building on past gains.

The challenges addressed by aquaculture research, like all research, are multifaceted and complex. The organisms, production systems, environment, cost of inputs, and value of outputs are all changing dynamically. Oftentimes, out of necessity, research will focus on one piece of a large system or one new technology, like the disease resistance and susceptibility of a new hybrid catfish. Simultaneously, other scientists will be working on a different piece, such as improving oxygen-management systems.

Generally, no single technology by itself will transform an industry. Instead, a series of improvements is needed, each of which takes time in development and in extension and transfer. Benefits will accumulate as farmers adopt the new technology—a process estimated to take 15 to 30 years.

The catfish industry has been beset by many of the same troubles seen in other animal-production industries. The high price of feed and fuel has driven up production costs. One factor the catfish industry has to deal with, which is less severe for those in the poultry, beef, or swine industries, is the easy substitution of catfish with other white-fleshed fish, such as tilapia. When the price of beef goes up, people eat less beef; but when they do buy beef, it is generally beef that was produced in the United States. On the other hand, if the cost of catfish goes up, consumers may look to similar products, often produced outside the United States, that can fill the same niche at a lower price. This has made the factors affecting the cost of catfish production especially critical.

Advances in Catfish Research

In this issue, you will read about advances in producing farm-raised catfish. The research by ARS, Mississippi State University and other university partners, and industry scientists has been uniquely collaborative, leading to innovations that could potentially double the historical levels of production from 4,000 pounds per acre to more than 8,000 pounds. Production of a new hybrid catfish (blue catfish male by channel catfish female) has increased dramatically, from 30 million fry in 2007 to more than 150 million in 2012, and it will likely exceed 175 million in 2013. New aeration strategies have resulted in improved feeding and better conversion of feed into fillet. These cumulative advances result in shorter production cycles, improved rates of survival, and higher profitability. (See story on page 4.)

As the interest in hybrid production grows, ARS scientists at our Stoneville, Mississippi, location are making inroads into genetic improvements, discovering better methods of hybrid juvenile production, and enhancing pond systems—research that will help farmers deliver high-quality catfish to meet consumer demand.

Catfish strains are regularly evaluated to help farmers and processors improve traits and increase profits. ARS scientists are identifying the best blue males and channel females to produce hybrid offspring with superior growth and fillet yield. They also investigate whether the performance of purebred channel catfish offspring is predictive of the best female parents for hybrid production. This information will benefit producers as they develop breeding plans to improve catfish performance.

Channel catfish have been well characterized for several decades, but there is less data on blue catfish production traits and blue-by-channel hybrid catfish offspring. Research at Stoneville will determine the effects of blue catfish strains and individuals within strains on hybrid offspring growth and fillet yield.

Several scientific advances are being developed and incorporated into catfish farming. ARS scientists developed a set of molecular markers for DNA fingerprinting to efficiently identify catfish species and parentage. They tested the markers on different populations and were able to identify the parents of offspring collected over 3 years and attribute all individuals to specific crosses. This accuracy allows for greater and faster genetic gains in performance.

Strategies for progress also include selective breeding to improve disease resistance, enhancing vaccine treatment to protect against pathogens, and developing better pond-management systems and equipment. As soon as they are available and tested, these improvements are passed on to farmers.

ARS remains committed to delivering relevant, high-quality research that benefits the aquaculture industry. This includes working with the U.S. catfish industry to develop the tools and technology it needs to improve productivity, efficiency, and quality so that it may rebound and thrive. The work of ARS scientists and collaborators has provided new knowledge and technology that is contributing to a renewed domestic catfish industry.

Jeff Silverstein
ARS National Program Leader
Aquaculture
Beltsville, Maryland

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ECOVATIVE (D3063-1)

Biomass packaging material created using technology developed by ARS, collaborators, and Ecovative can be made to custom fit a wide variety of products. Story begins on page 16.

Cover: ARS geneticist Brian Bosworth (left) and animal caretaker Reese Mascagni oversee loading of market-size catfish on a fish-hauling truck. Excess fish produced by the ARS research program are often sold to processing plants. Story begins on page 4. Photo by Les Torrans. (D3027-1)

Producing Better Catfish

LES TORRANS (D3031-1)

ARS geneticist Nagaraj Chatakondi (second from right) from the Warmwater Aquaculture Research Unit in Stoneville, Mississippi, holds a fully mature female catfish in a broodfish pond while training the hatchery crew at a commercial hybrid catfish production facility in Arkansas. Through hands-on training, ARS scientists are taking their hybrid catfish production techniques to the farmer.

The catfish once ranked pretty far down among fish species as a lowly bottom feeder, but that was when it could only be caught in the wild. With the birth of freshwater catfish farming in the 1960s, the catfish has made a big splash, netting the number-one spot in the U.S. aquaculture industry.

However, in recent years, U.S. catfish producers have been struggling to keep their heads above water, avoiding the waves of a slow economy, high feed costs, and fish imports from foreign countries. Sales of catfish products were down to about $341 million in 2012 from $423 million in 2011, and acreage has declined in the major catfish producing states—Alabama, Arkansas, Louisiana, and Mississippi.

To help farmers, Agricultural Research Service scientists in the Warmwater Aquaculture Research Unit (WARU) and their Mississippi State University (MSU) colleagues at the Thad Cochran National Warmwater Aquaculture Center in Stoneville, Mississippi, are looking at breeding, nutrition, genetics, and management practices to produce a better catfish. For decades, it's been known that hybrid catfish—a cross of the fast-growing channel catfish with its close relative, the slower growing and larger blue catfish—generally have better growth, higher survival, and better meat yield than either channel or blue catfish. But hybrids have been difficult to produce in large quantities. That's changing.

Hybrid catfish production has increased substantially—comprising about 20 percent of catfish harvested in 2011. In 2007, catfish hatcheries produced 30 million hybrid fry. That number is now estimated to be 150 million hybrid fry.

ARS scientists have refined the hybrid breeding process and are taking the technology directly to catfish farmers. "Our hybrid work is based on solid science, but what's making a tremendous impact is our outreach effort to get the technology out and rapidly implement it in the industry," says WARU researcher leader Craig Tucker.

How To Make a Hybrid

"Our best chance for a quick impact on hybrid production was to help farmers learn how to make what we call the 'fry,' or baby fish, which was new to them," says geneticist Brian Bosworth.

Bosworth and geneticist Nagaraj Chatakondi are conducting workshops for farmers, in collaboration with MSU scientists, to demonstrate how to produce hybrid catfish fry in hatcheries. They also give on-site consultations at hatcheries.

To produce channel catfish, farmers typically place "spawning cans" in ponds containing mature males and females, Bosworth says. The females lay eggs inside the cans, and the males then fertilize the eggs.

The hybrid catfish, however, is a cross between two different species that do not mate with each other naturally. Hybrid

Two-year-old blue catfish being released in a pond for future use as brood stock in hybrid production. ARS scientists have improved cross breeding of blue and channel catfish, which produces the hybrid.

LES TORRANS (D3029-1)

the Hybrid Way

LES TORRANS (D3032-1)

Hybrid fry are maintained in hatcheries until they reach swim-up stage and begin to eat commercial fry feed. These fry are turning black, a sign that they are nearly old enough to accept feed. ARS research is helping to raise the efficiency and lower the cost of hybrid catfish fry production.

fry production involves hormone-assisted reproduction. The female channel catfish is given a hormone injection, which induces her to ovulate—release eggs. The fish is anesthetized, and eggs are "stripped," meaning gently pushed out. Sperm taken from blue catfish males is mixed onto the eggs. Hands-on training involves teaching farmers the process, ensuring that the hormone dosages and egg and sperm preparations are right, and dealing with any other issues.

"Once eggs have hatched, production is pretty much the same as with regular channel catfish," Chatakondi says. "The only difference is that hybrid catfish generally grow much faster and are easier to harvest and process. Farmers can increase production 20 to 30 percent by using hybrids instead of channel catfish."

Still, many farmers prefer channel catfish because fry production costs are lower than those for hybrids, and more channel fingerlings (juvenile fish) are available.

Overcoming Inefficiencies in Hybrid Production

Factors such as inconsistencies in egg quality and suboptimal hatching conditions increase the cost of hybrid fry production. "We need to find ways to improve efficiency of hybrid embryo production in catfish hatcheries," Chatakondi says.

One approach is to look at the effects of water quality, such as its calcium content, or "hardness," on the hatching success of eggs. Working with fish biologist Les Torrans, Chatakondi incubated fertilized hybrid eggs in waters containing four levels of calcium hardness to determine which level yields the highest hatching success. The calcium hardness levels ranged from 25 milligrams per liter to 100 milligrams per liter—levels maintained by commercial hybrid hatcheries. They found that lower calcium levels may reduce hatchability and increase vulnerability to diseases.

"We recommend a calcium hardness level of 75 milligrams per liter in waters to hatch hybrid catfish eggs," he says. "Optimal levels improve the egg-hatching success and may contribute to a lower cost of producing hybrid fingerlings."

Additionally, not all eggs are created equal. Hormone-induced fish often ovulate eggs that vary in quality due to variation in brood fish maturity, husbandry, nutrition, genetics, and mechanical damage during manual spawning. Poor-quality eggs are more vulnerable to fungi, which could spread to healthy eggs.

Chatakondi developed a method, which can be easily adopted in catfish hatcheries, to identify poor-quality eggs before they hatch. He found that the pH level of ovarian fluid of stripped channel catfish eggs prior to fertilization can be used to predict hatching success in hybrid embryos.

It appears that a pH level of more than 7.0 is indicative of better quality eggs, and using egg lots of this pH or higher can improve hatching rate, Chatakondi says.

Genetic Tools for Breeding

Scientists are constructing a genetic map of the catfish genome to identify chromosomal regions that control significant traits—such as meat yield and disease resistance—that are essential for selective breeding programs.

Molecular biologist Geoff Waldbieser has developed DNA markers to analyze channel catfish parentage and kinship to determine genetic diversity, produce pedigree populations, and identify markers associated with important traits. This technology is being used to learn more about genetic background to further improve hybrid performance. In a recent study, hybrids were grown in ponds and then measured for growth and meat yield. The analysis indicated the presence of substantial genetic effects of parents on offspring performance.

"This shows we can improve hybrid catfish growth and carcass yield by selecting superior female channel catfish and male blue catfish parents," Bosworth says.

LES TORRANS (D3033-1)

Animal caretaker Mike Lofton weighs a basket of hybrid catfish going to a processor. The fast-growing, meaty hybrid is a cross between the blue and channel catfish.

Waldbieser also designed a rapid DNA-based test that identifies and distinguishes channel, blue, and hybrid catfish within 24 hours at all life stages, from 1 day after fertilization to a cooked fillet. "The test is a useful tool for hybrid production management and postharvest detection of hybrid catfish products," he says.

In other research, physiologist Brian Peterson investigated the relationship between catfish growth, immune function, and genes during early stages of development. Egg samples were taken before and after fertilization, and embryos were collected at hatch and at "swim-up"—the stage when fry are not yet sexually developed.

Peterson examined changes in gene expression of insulin-like growth factors (IGFs) and toll-like receptors (TLRs), molecules involved in the induction of the immune response, in hybrid and channel catfish. Over time, gene expression levels of TLR5 and IGF-I mRNA increased in channel catfish. In hybrids, TLR3, IGF-I, and IGF-II mRNA increased.

"It was known in mammalian species that IGF-II played a primary role in fetal development. The biggest surprise in our catfish studies was that IGF-II plays a role in both fetal development and juvenile growth," Peterson says. "IGF-I in catfish also plays a role during fetal development and growth."

Making the Grade Against Disease

Proliferative gill disease (PGD) is one of the most devastating parasitic infections affecting catfish. The deadly disease damages the gills of fish and decreases their ability to get oxygen from water.

To find out if hybrids are more or less susceptible to PGD, Bosworth and his colleagues looked at gill damage in different lines of channel, hybrid, and blue catfish. Juvenile catfish were placed in a commercial pond where catfish deaths were attributed to PGD. They then identified and examined channel catfish and hybrid families with the most gill damage and those with the least gill damage.

"The consistent differences we observed in gill damage between resistant and susceptible families after PGD infection suggest a genetic component for PGD resistance," Bosworth says. "Therefore, it could be possible to improve PGD resistance through genetic selection."

Selecting Superior Fish

Scientists routinely evaluate and identify catfish strains with superior performance to help farmers and processors improve traits and increase their profits. In one study, three genetic groups of catfish—NWAC103 line channel catfish, Norris line channel catfish, and a hybrid between the Norris channel catfish and the Dycus Farm line blue catfish—were compared for production, meat yield, and meat quality traits. Juvenile fish were stocked in ponds, fed, and harvested after 200 days. Fish were weighed, counted, processed, and measured for meat and body component yield. Fresh, frozen-thawed, and baked fillets were measured for quality.

NWAC103 grew faster and had higher production than the other groups. But the hybrid had higher meat yield than either of the channel catfish lines. No difference was found in weight gain, survival, and feed conversion among groups.

In a separate study, Bosworth looked at winter feeding effects on growth, body composition, and processing traits of blue, channel, and hybrid catfish and found that hybrids gained the most weight among fed fish. Carcass yield was consistently higher for blue catfish and hybrids than for channel catfish, and fillet yield was higher for hybrids than other fish.

Although the catfish industry has taken a blow, further research on hybrids may yield what many farmers need to get back on the road to recovery. Work continues to determine desirable heritable traits of catfish, improve germplasm for commercial production, and identify water-quality variables that limit production.

"I'm looking at how much better the hybrid fish is now and how much better these production systems have the potential to be, and I really think it is having an impact on the industry," Bosworth says.—By **Sandra Avant,** ARS.

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

*To reach scientists mentioned in this article, contact Sandra Avant, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; (301) 504-1627, sandra.avant@ars.usda.gov.**

Airing Out Catfish Oxygen Needs

Catfish farmers can breathe a sigh of relief. Years of research on dissolved oxygen (DO) management, the most critical water-quality factor in aquaculture, is paying off.

"As you feed fish, phytoplankton also grow—producing oxygen in the daytime and consuming it at night," says fish biologist Eugene Les Torrans, who is in the Agricultural Research Service's Warmwater Aquaculture Research Unit (WARU) at the Thad Cochran National Warmwater Aquaculture Center in Stoneville, Mississippi. "If you feed too much, oxygen gets too low, and fish can die."

Traditionally, oxygen management was based on farmers' observations. If fish were seen at the water surface sucking oxygen in the morning, aeration equipment was turned on. If no fish were seen, it was presumed there was enough oxygen.

Torrans's experience and research has shown otherwise. "There's a DO concentration at which fish die and a little higher DO at which they survive, but are responding to stress," he says. "In the daytime, DO can get as high as 14 parts per million (ppm), and if it gets down to 3 ppm at night, fish are still fine. But when DO drops lower, the fish become partially asphyxiated."

LES TORRANS (D3030-2)

Ten-horsepower paddlewheel aerators (shown here) allow catfish farmers to adjust dissolved oxygen (DO) concentrations in their ponds. ARS scientists have determined the minimum DO level needed to improve growth, shorten the production cycle, reduce fish losses, and improve feed conversion.

Fish first respond to oxygen stress by losing their appetite. When DO drops too low in the morning, fish eat less feed. "As a result, the production cycle increases," Torrans says. "Instead of fish growing out in 2 years, it takes 4 years and sometimes 5 years."

Torrans examined the impact of DO concentration on channel, blue, and hybrid catfish growth, yield, food consumption, and feed conversion. A computer-controlled pond-oxygen monitoring system was used to maintain precise DO levels in the morning—3.0, 2.0, and 1.5 ppm. Scientists found that a DO level of 3.0 ppm is required for optimum production. These minimum DO concentrations improve growth, significantly shorten the production cycle, reduce fish losses, and greatly improve food conversion.

"This revelation has changed the industry's oxygen-management practices," says WARU research leader Craig Tucker. "We have gone from keeping fish alive to keeping them growing. You can double the growth rate of the fish in your pond by managing oxygen. It's pretty incredible."

"We're trying to reduce production costs as much as possible," Torrans says. "We now have exact numbers in terms of how much aeration is needed to maximize fish food intake, growth, and production.—By **Sandra Avant,** ARS.

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

*Les Torrans is in the USDA-ARS Warmwater Aquaculture Research Unit, P.O. Box 38, Stoneville, MS 38776; (662) 686-3595, les.torrans@ars.usda.gov.**

Dairy Farms Are Not a Source of Far-Flung Bioaerosols

Sampling equipment (left) is set up on the downwind side of cattle pens to measure the amount of bioaerosols, such as endotoxins, bacteria, and fungi, in the air near the pens.

ROB DUNGAN (D3043-1)

In the late afternoon, when fidgety dairy cows start milling around, they stir up a heavy layer of dust that hangs over the yard. This airborne dust does more than signal potential rowdiness among the livestock. It contains bacteria, viruses, fungi, and small bacterial remnants called "endotoxins," which can be dispersed through the air beyond the facilities to the surrounding landscape.

These airborne microorganisms and their byproducts and remnants are also called "bioaerosols." Agricultural Research Service microbiologist Rob Dungan is documenting how bioaerosol dispersal fluctuates throughout the day and year, their downwind concentrations, and factors that affect dispersal patterns.

"In the western United States, dairy cows are kept in large outdoor pens or in a combination of exercise pens and barns at open-freestall facilities. Either way, people can sometimes smell dairies before they can see them, so they assume there's a problem," says Dungan, who works at the Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho. "There's a lot of interest from people in nearby communities in finding out more about their potential exposure to airborne endotoxins and other bioaerosols from these facilities."

Distance Makes All the Difference

For one study, Dungan, soil scientist April Leytem, and research leader David Bjorneberg set up three sampling sites at a 10,000-cow open-freestall dairy to measure airborne endotoxins and culturable microorganisms like bacteria and fungi during fall, spring, and summer. One site was slightly more than a tenth of a mile upwind of the facility. A second site was 165 feet downwind from a barn, and the third was 655 feet (about a tenth of a mile) downwind from the same barn.

The researchers found that overall average inhalable airborne endotoxin concentrations were 5 endotoxin units (EU) per cubic meter at the upwind site, 426 EU downwind near the barn, and 56 EU farther downwind. At the upwind and the distant downwind sites, endotoxin concentrations did not vary significantly over 24 hours. But closer to the barn, nighttime endotoxin concentrations were significantly higher than morning concentrations and were similar to afternoon concentrations—increases the scientists attribute to increased animal activity and lower wind speeds during these times.

Analysis of bacterial concentrations showed a similar pattern. Average bacterial counts over the sampling period were 2,800 colony forming units (CFU) per cubic meter of air at the upwind site; 84,000 CFU 165 feet downwind of the barn; and 7,900 CFU 655 feet from the barn. As with the daily endotoxin concentrations, bacterial concentrations near the barn increased significantly at night, but concentrations farther downwind did not.

When the scientists compared concentration fluctuations with weather conditions, they noted that endotoxin concentrations rose with air temperature. Meanwhile, airborne bacteria concentrations increased when air temperatures and wind speeds increased, but dropped when solar radiation and relative humidity increased.

No Lasting Effects

Dungan and Leytem conducted another investigation at a 10,000-cow open-lot dairy. For this study, they sampled airborne endotoxin concentrations at an upwind site about one-tenth of a mile from the lot, at a downwind site at the edge of the lot, and at the dairy perimeters, which were more than three-quarters of a mile downwind of the lot.

Average endotoxin concentrations at the downwind edge of the open lots were about 11 times higher than the concentrations upwind, while the endotoxin concentrations at the most distant downwind site were found to be statistically similar to those at the upwind site.

The scientists determined that the primary factors affecting airborne endotoxin emissions were wind speed, lot management, and animal activity. As expected, the scientists observed that endotoxin suspension and transport from the animal housing areas increased as wind speed increased and as animal activity increased. Other lot-management practices, including breaking up the manure with harrowing, also generated higher airborne endotoxin concentrations.

Unlike airborne microbes like bacteria and fungi, endotoxins are highly resistant to solar radiation and temperature. The researchers did not observe any significant correlations between fluctuations in endotoxin levels and changes in air temperature, solar radiation, or relative humidity.

"As with other types of livestock facilities, dairies are a source of bioaerosols because they house many animals that generate lots of manure," says Dungan. "But our data shows that bioaerosol concentrations reach normal background levels at a fairly short distance from their source at the dairies. So people who live near these facilities can hopefully breathe a sigh of relief about potential bioaerosol exposures."—By **Ann Perry,** ARS.

This research is part of Agricultural and Industrial Byproducts (#214) and Climate Change, Soils, and Emissions (#212), two ARS national programs described at www.nps.ars.usda.gov.

*Robert Dungan, April Leytem, and David Bjorneberg are with the USDA-ARS Northwest Irrigation and Soils Research Laboratory, 3793 North 3600 East, Kimberly, ID 83341; (208) 423-5582, robert.dungan@ars.usda.gov, april.leytem@ars.usda.gov, dave.bjorneberg@ars.usda.gov.**

ARS microbiologist Rob Dungan sets up a type of sampling equipment known as a "glass impinger," which is used to capture airborne microorganisms, or bioaerosols.

ROB DUNGAN (D3047-1)

Protecting Water Near Feedlots

Intensive management practices used on cattle feedlot sites can produce large concentrations of manure with excess nutrients, antibiotics, and microorganisms. The contaminants may end up in surface and ground waters, and minimizing such damage is important to feedlot operators. This is particularly challenging in Kentucky, where the limestone and "karst" terrain offers contaminants subterranean passage into underground caves, springs, and sinkholes. Cleaning up these sites is costly, and the big question is how to apply resources to the right areas. Spatial sampling and mapping is one of the best tools available to identify the most intensively contaminated areas, find out how contaminants have spread, and decide which areas need the most attention. The ultimate goal is to help producers develop management strategies that minimize contaminant loads.

Kim Cook and Karamat Sistani, at the Agricultural Research Service's Animal Waste Management Research Unit, in Bowling Green, Kentucky, along with collaborators at Western Kentucky University in Bowling Green and at ARS in Beltsville, Maryland, are using GIS (geographic information system) technologies to map the distribution of contaminants across feedlot sites. Their approach is unique in its use of the technology to determine not just how nutrients flow through the soil, but also the fate of bacteria and pharmaceuticals given to cattle to protect their health.

The team measured the levels of contaminants in soil samples collected from a 5-acre feedlot used to grow out weaned calves for finishing. The site lies on a 4-degree slope with a feeding and watering area at the highest elevation, a grassy grazing area in the middle, and a shallow retention basin and sinkhole at the bottom. Most rainwater percolates into the soil, but heavy rain can cause flooding that fills the basin with water from the grazing area.

The researchers analyzed the soil for nutrients, including nitrogen and phosphorus; antibiotics used to treat diseases and enhance growth; and for microorganisms commonly used to indicate fecal contamination in waterways and soils—*Escherichia coli*, *Bacteroides,* and *Enterococcus*. The study was one of the first to simultaneously measure all three types of contaminants—nutrients, antibiotics, and indicator microorganisms—and to use GIS technology to map patterns of contaminant distribution.

The results, published in the *Journal of Environmental Quality* (2013), showed that nutrients, microorganisms, and antibiotics all largely stayed in the feeding area at the top of the slope.

"Analysis of contaminants, particularly antibiotics and microorganisms, on this scale is not very common. Incorporating the GIS mapping allowed us to visualize the distribution of all three contaminants in new ways. We were surprised to find that all were distributed in a similar manner and there was no distinct flow pattern downhill from the barn," Cook says. The findings suggest that cleaning up the site may be more manageable than previously thought, with efforts focused on soil remediation in the feeding and nearby grazing areas where contaminants are concentrated.

To reduce nutrient loads, forage grasses that take up nutrients are now being raised on part of the site. The researchers are also evaluating soil treatments (alum, biochar, and gypsum) in the most contaminated areas to see if they will bind with the nutrients, antibiotics, and microorganisms and give them time to decompose in the soil.—By **Dennis O'Brien,** ARS.

This research is part of Climate Change, Soils, and Emissions (#212) and Agricultural and Industrial Byproducts (#214), two ARS national programs described at www.nps.ars.usda.gov.

*Kim Cook is in the USDA-ARS Animal Waste Management Research Unit, 230 Bennett Ln., Bowling Green, KY 42104; (270) 781-2579 ext. 232, kim.cook@ars.usda.gov.**

ARS microbiologist Kim Cook (right) and Western Kentucky University soil scientist Annesly Netthisinghe collect soil samples from a 5-acre experimental feedlot in western Kentucky for analysis of nutrients, antibiotics, and microorganisms.

JASON SIMMONS (K3045-1)

Breadfruit Not So Appetizing to Mosquitoes

A tropical food that's being hailed by many as a possible solution to world hunger also contains compounds that could help prevent mosquitoes from spreading serious and deadly diseases such as malaria, yellow fever, and dengue fever.

Breadfruit, *Artocarpus altilis,* is a tropical staple food crop traditionally cultivated for more than 3,000 years throughout Oceania—Melanesia, Micronesia, and Polynesia. The fruit is plentiful, starchy, and packed with nutrients. In addition to being a valuable, nutritious food, breadfruit is used in Hawaii and other regions to control insects. People burn dried clusters of flowers—technically known as "male inflorescences"—to repel flying insects, including mosquitoes.

Scientists from the Agricultural Research Service and Canada's University of British Columbia teamed together to identify the natural chemicals in breadfruit that deter insects.

"We found that three chemicals—capric, undecanoic, and lauric acids—were responsible for the repellent activity," says Charles Cantrell, a chemist at the ARS Natural Products Utilization Research Unit (NPURU) in Oxford, Mississippi. "These chemicals are also known as C10, C11, and C12 saturated fatty acids."

Male inflorescences from a diverse selection of breadfruit trees were sun dried at the National Tropical Botanical Garden's Breadfruit Institute in Kalaheo, Hawaii, and provided to scientists for testing. ARS scientists collected smoke samples as they burned the inflorescences in the traditional method used in Pacific regions. More than 30 compounds in the smoke were identified, including a mixture of terpenes, aldehydes, fatty acids, and aromatics.

PEGGY GREB (K3056-1)

A mosquito feeding through an artificial membrane and blood substitute. In this test, ARS scientists found that when chemical extracts from breadfruit were applied to the membrane, mosquitoes did not feed.

At the ARS Invasive Insect Biocontrol and Behavior Laboratory in Beltsville, Maryland, chemist Kamal Chauhan tested the compounds' effectiveness against adult *Aedes aegypti* female mosquitoes in a blood-feeding membrane system that mosquitoes feed upon as if it were a human.

"These natural chemicals were significantly more effective at repelling mosquitoes than DEET, the primary insecticide against biting insects," Chauhan says. "In regions where they're available, dried clusters of breadfruit flowers can be used by people who may not be able to afford expensive repellent products."

"This was the first research to show that breadfruit really works as a repellent, validating a folk remedy," Cantrell says.

In a separate study, NPURU scientists looked at a wide range of saturated and unsaturated fatty acids and discovered similar results. "These same three chemicals found in breadfruit and other folk remedies were highly active and the most repellent fatty acids that we've seen," Cantrell says.

Chemist Uli Bernier, in the Mosquito and Fly Research Unit at the Center for Medical, Agricultural, and Veterinary Entomology in Gainesville, Florida, used a standard repellency test to evaluate the compounds against mosquitoes. The test uses volunteers who wear cloth treated with various concentrations of the chemicals. Bernier verified that the saturated fatty acids provide effective protection.

These studies were partially funded by the Deployed War-Fighter Protection Research Program, which develops and improves methods to protect U.S. military personnel from disease-transmitting insects.—By **Sandra Avant,** ARS.

This research is part of Veterinary, Medical, and Urban Entomology, an ARS national program (#104) described at www.nps.ars.usda.gov.

*To reach scientists mentioned in this article, contact Sandra Avant, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5128; (301) 504-1627, sandra.avant@ars.usda.gov.**

Better White Layer Cakes Ahead?

Experiments led by Agricultural Research Service food technologist Mukti Singh are showing how to boost the fiber content in white layer cake—or lower the calories—without significantly undermining many of the key qualities of this all-time-favorite dessert.

Singh's edible-fiber experiments focused on corn bran, the corn kernel's fiber-rich outer layer. She determined that purified, finely ground corn bran can be used as a substitute for up to 20 percent of the flour called for in the American Association of Cereal Chemists' "gold standard" test recipe for white cake. That amount of fiber didn't significantly affect qualities such as color, crumb grain size (an indicator of structure), volume, moisture (moist—but not soggy—is ideal), and springiness (the unfrosted top surface of a good cake will spring back when gently touched).

What's more, the 25 volunteer taste-testers who sampled the 20-percent-corn-bran-enhanced cake rated it as "acceptable." In taste-tester lingo, that counts as a vote of confidence.

Singh estimates that one slice of an 8-inch, six-slice, two-layer white cake made with that amount of bran would provide about 5 grams of healthful fiber. A slice from a standard white layer cake would provide about 1 gram.

A peer-reviewed scientific article that Singh and colleagues Steven F. Vaughn and Sean X. Liu, all with the ARS National Center for Agricultural Utilization Research in Peoria, Illinois, published in 2012 in *Biocatalysis and Agricultural Biotechnology* has details that may interest bakers and companies that make cake mixes for commercial or home baking.

The study is apparently among the few that provide publicly accessible data about the effects that relatively high concentrations of purified, finely ground corn bran can have on the quality of white cake.

STEPHEN AUSMUS (D3066-1)

Bakery cakes like this one may one day have more fiber. ARS scientists are using finely ground corn bran as a substitute for some of the flour used to make white layer cake, raising its fiber content without sacrificing quality. Additional research is aimed at reducing the confection's calorie content.

In tests aimed at cutting calories—without sacrificing quality—Singh worked with a patented, ARS-developed process that uses steam-jet cooking to encapsulate microdroplets of cooking oil (in this case, canola) with flour and water. The cream-textured mixture that results can then be dried to form a smooth-flowing, shelf-stable powder that's ready for the mixing bowl.

Explains Singh, "Encapsulation helps distribute the oil evenly throughout the cake, so you can use less of it and still have some of the smooth mouthfeel of a higher oil, higher calorie cake." And the approach offers busy bakers the convenience of having oil already included in the mix, so there's no need for pouring, measuring, or cleanup of this ingredient.

In these tests, Singh used only 25 percent of the cooking oil called for in the standard test recipe. She showed that cakes made with the flour-oil-water "composites" were softer and springier, and stayed moist longer, than cakes made with the same amount of nonencapsulated flour and oil.

Noted briefly in *Agricultural Research* in March 2010, the work was reported in detail in the *Journal of Food Processing and Technology* in 2012. The study presents what is likely the first data, published in a scientific research journal, about use of the composites in cake. The findings provide a foundation for further research and development, including taste-testing.—By **Marcia Wood,** ARS.

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

*Mukti Singh is with the USDA-ARS National Center for Agricultural Utilization Research, Functional Foods Research Unit, 1815 N. University St., Peoria, IL 60605; (309) 681-6357, mukti.singh@ars.usda.gov.**

Breakfast Helps Kids Handle Basic Math, Study Suggests

Even people who know a lot about the human brain may be impressed by the extent to which eating a single breakfast—or skipping it—can influence a child's ability to solve math problems.

Just ask scientist Terry Pivik, whose research with 81 children has shown that those who ate breakfast were better able to tackle dozens of math problems in rapid-fire succession than peers who didn't have a morning meal.

As a psychophysiologist, Pivik studies how our brains influence our behavior. Based in Little Rock, Arkansas, he directs the Brain Function Laboratory at the Agricultural Research Service-funded Arkansas Children's Nutrition Center and is a research professor in pediatrics at the University of Arkansas for Medical Sciences.

In his study of healthy 8- to 11-year-old volunteers, Pivik used EEG (electroencephalographic) sensors to harmlessly record electrical activity generated in regions of children's brains involved in solving math problems. The sensors were fitted into a soft cap that the youngsters wore as they viewed simple math problems presented to them on a computer monitor, calculated the answer in their heads, and then quickly selected one answer from among three onscreen choices.

In all, the kids had a little more than 1 second to process each problem.

Each child took two math tests in the morning. Half of the children ate breakfast during a break in the testing; the others did not.

Factors that could skew results were carefully controlled. For example, to prevent sleepiness, a watchful nurse and a wristband-mounted monitor that the volunteers wore ensured that each child had a full 8 hours of rest the night before the tests.

EEG data showed that "children who skipped breakfast had to exert more effort to perform the mental math that the tests required and to stay focused on the task at hand," says Pivik. "In contrast, those who ate the breakfast that we provided used less mental effort to solve the problems, stayed more focused on the tests, and improved their scores in the post-breakfast test."

PEGGY GREB (D1678-2)

An ARS-funded study with children ages 8-11 showed that starting the day with breakfast can enhance the ability to solve math problems.

Previous studies by researchers elsewhere have shown an association between nutrition and academic performance. However, the design of the Arkansas study had some important differences. "We carefully controlled when the kids either had breakfast or skipped it, and what they ate," Pivik explains. "To the best of our knowledge, this is the first published study, with kids of this age group, that both controlled the morning meal and used EEG technology to monitor brain activity while the children were processing mathematical information."

Pivik and nutrition center colleagues Yuyuan Gu and Kevin B. Tennal, along with Stephen D. Chapman—formerly at the center—published their findings in a peer-reviewed article in *Physiology & Behavior* in 2012.

The research is part of ongoing investigations in Pivik's lab to discover more about how to nourish the brain and enhance children's ability to learn. "There's much more to uncover about the role that nutrition plays in influencing the neural networks that kids engage when they're doing mental arithmetic," Pivik says. "We're addressing this knowledge gap because math skills are so critical in today's world."—By **Marcia Wood,** ARS.

This research is part of Human Nutrition, an ARS national program (#107) described at www.nps.ars.usda.gov.

*R. Terry Pivik is with the USDA-ARS Arkansas Children's Nutrition Center, 15 Children's Way, Little Rock, AR 72202; (501) 364-3346, pivikterry@uams.edu.**

Greenhouse Gas Emissions and Yields from Organic and Conventional Systems

"Our human activities affect the environment, so agriculture is likely to leave a footprint," says Agricultural Research Service soil scientist Jane Johnson. "What we need to know is what we can do to reduce that footprint."

As part of that goal, Johnson led a study to see whether reduced-tillage organic and conventional production systems differed in yields or in the emission of greenhouses gases that have greater global warming effects than carbon dioxide, like methane and nitrous oxide. That is, would greenhouse gas emissions from an acre of conventional corn exceed greenhouse gas emissions from an acre of organic corn, or vice versa?

Johnson works at the ARS North Central Soil Conservation Research Laboratory in Morris, Minnesota. Her project team included Morris soil scientist Sharon Weyers and biologist Nancy Barbour, as well as agricultural scientist David Archer, who works at the ARS Northern Great Plains Research Laboratory in Mandan, North Dakota.

The scientists studied yields from organic and conventional production of a 4-year corn-soybean-wheat-alfalfa rotation in Minnesota. While both systems relied primarily on alfalfa for nitrogen, the conventional plots were also amended with urea-based fertilizer, while the organically managed plots were amended with solid dairy manure. This meant that during the study period, the conventional systems received 590 pounds of synthetic nitrogen, almost twice as much as the organic systems received via dairy manure amendments.

The team used closed-vented chambers to monitor greenhouse gas emissions for 3 years during the growing season from May to November, as well as during early spring thaws. They found that both systems produced similar corn grain yields during 2007. But organic corn yields were 60 percent lower than conventional corn yields in 2006 and 40 percent lower during 2008.

During 2007 and 2008, organic and conventional soybean yields were similar, but 2006 organic soybean yields were 90 percent lower than conventional yields. In 2006, organic wheat yields were 50 percent lower than conventional wheat yields.

Field measurements of greenhouse gas emissions indicated that both systems emitted 3.75 pounds of nitrous oxide per acre every year—measurements that cumulatively represent 4.74 percent of the nitrogen added to the conventional system and 9.26 percent of the nitrogen added to the organic system. This meant that the nitrous oxide emissions per unit of nitrogen applied were nearly twice as large from the organically managed system as from the conventionally managed system.

The scientists believe that the greater biomass production in the conventional system and the lower productivity of the organic system indicate that the conventional crops were able to use applied nitrogen more effectively to support plant growth. Because the yield was lower from the organic system, the nitrous oxide footprint per unit of crop yield was greater in the organic system than in the conventional system.

"This study suggests that the ability of organic production to mitigate greenhouse gas may be less attractive to producers if it also results in lower yields. This emphasizes the importance of management to maintain crop productivity in any system," Johnson says.—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.

*Jane Johnson is with the USDA-ARS North Central Soil Conservation Research Laboratory, 803 Iowa Ave., Morris, MN 56267; (320) 589-3411 ext. 131, jane.johnson@ars.usda.gov.**

STEPHEN AUSMUS (D1621-5)

Using closed vented chambers, biological science aide Rochelle Jansen (right) and soil scientist Jane Johnson collect gas emissions from soil at a research farm. Samples will be analyzed for carbon dioxide, nitrous oxide, and methane.

LYNN LIBBOUS-BAILEY (D1484-1)

Fungus Takes Down Another Weed

Plant pathologist Doug Boyette prepares a fermenter for growing fungus. Boyette and collaborators have found a fungus that may control Palmer amaranth, an aggressive weed that is developing resistance to some herbicides.

Palmer amaranth is an aggressive southern weed that can grow at the rate of 2 inches a day and outcompete corn, cotton, soybean, and other crops for resources at the cost of their full yield potential.

To make matters worse, the prodigious flowering weed has built up resistance to glyphosate, the main herbicide used to control it, prompting a search for alternatives. One possibility being explored by Agricultural Research Service scientists in Stoneville, Mississippi, is the fungus *Myrothecium verrucaria*. Prior studies conducted there by Doug Boyette, Robert Hoagland, and others demonstrated *Myrothecium's* potential as a biologically based herbicide against sicklepod, kudzu, hemp sesbania, and other weeds. (See "Formidable Fungus Goes Toe to Toe With Kudzu," *Agricultural Research,* July 2009.)

Now, based on recent greenhouse trials, it appears the fungus will also infect and kill or weaken Palmer amaranth, including weed biotypes that can resist glyphosate and other herbicides, such as triazines. According to Hoagland, a chemist in ARS's Crop Production Systems Research Unit, *Myrothecium* attacks its weedy host's leaf and stem tissues, causing wilt, necrotic lesions, loss of chlorophyll, and other disease symptoms that can kill young plants and weaken older ones, rendering them less competitive with crops.

To test the infectivity of *Myrothecium*, the researchers used a filamentous growth stage of the fungus known as "mycelium" and sprayed a mycelial-surfactant formulation onto two batches of 4-week-old Palmer amaranth seedlings: those with glyphosate resistance and those without. They repeated the same procedure for 6-week-old plants. All groups were visually checked for symptoms over the experiment's 7-day (168-hour) period and weighed for reductions in shoot growth.

Seedlings were most susceptible, with all plants exposed to a full-strength application of the fungus showing disease symptoms. By 48 to 72 hours, nearly 100 percent had died. In 6-week-old plants, symptoms progressed more slowly, but there was no significant difference in injury between glyphosate-resistant and glyphosate-susceptible plants. Both groups showed disease symptoms, most notably chlorosis, some necrosis, and stunted growth.

The findings, which were published in the March 2013 *Allelopathy Journal,* mark the first report of *Myrothecium's* bioherbicidal activity against a weed species with glyphosate resistance. The research is a continuation of prior studies at Stoneville and elsewhere evaluating *Myrothecium's* host specificity, environmental safety, ease of production, and optimal delivery.

On a related front, the researchers are scrutinizing the genetic and biochemical mechanisms underpinning herbicide resistance in Palmer amaranth and other weeds. They have also begun studies on a strain of *Xanthomonas* bacteria found to infect the leaves of common cocklebur, marestail (or horseweed), and other herbicide-resistant threats to southern crops and potential targets for bioherbicide use.—By **Jan Suszkiw,** ARS.

This research is part of Crop Protection and Quarantine (#304) and Crop Production (#305), two ARS national programs described at www.nps.ars.usda.gov.

Robert Hoagland is in the USDA-ARS Crop Production Systems Research Unit, 141 Experiment Station Rd., Stoneville, MS, 38776-0350; (662) 686-5210, bob.hoagland@ars.usda.gov.

*Douglas Boyette is in the USDA-ARS Biological Control of Pests Research Unit, National Biological Control Laboratory, 59 Lee Rd., Stoneville, MS 38776; (662) 686-5217, doug.boyette@ars.usda.gov.**

Biodegradable Packaging

Summer flip-flops, garden planters, paver stones, and outdoor decking actually have something in common. If based on work conducted by Agricultural Research Service engineer Greg Holt and colleagues, all of these products can be made from agricultural waste and would biodegrade nicely.

Holt is working on a wide variety of composite materials using waste such as cotton burs, cotton seed hulls, cornstarch, gypsum, kenaf, flax, switchgrass, and wheat straw. He is with the ARS Cotton Production and Processing Research Unit in Lubbock, Texas.

One of Holt's recent projects is providing a type of biomass that is just right for use with a new process that literally grows custom packaging material. The process involves combining cotton gin waste and fungi inside a cast, called a "tool" where the two ingredients become one, resulting in a spongy-looking material similar in appearance to polystyrene foam. The custom-shaped end product is providing a cost-effective "green" alternative to extruded polystyrene foam packaging—an estimated $2 billon market. Products include custom packaging that protects, for example, computers and other breakables during shipping.

Holt's industry partner—New York-based Ecovative Design—developed the patented method that uses fungi as a workhorse. The technology uses the fungal growth stage, called "mycelium." First, woody cotton waste is blended, pasteurized, and embedded into a customized cast tool. Then, the tool is injected with the fungus. The mycelium grows onto, in, and around the cotton waste, eventually forming a new, consistently textured, solid mass. Once the tool is opened, a custom-shaped bio-package emerges that is then put into a kiln-like oven, where the live fungi are killed.

"The final formed protective package insulation is biodegradable, compostable, and flame retardant, yet it has the cushioning strength of synthetic packing material," says Holt. Ecovative Design is manufacturing these cost-competitive packaging parts for their corporate clients, including Dell, Steelcase, Crate & Barrel, and others.

GREG HOLT (D3061-1)

ARS and collaborators developed this biomass pressboard, made from a blend of cotton burr and pine fibers, for use as building material.

Which Waste Works Best?

In a test of types of gin waste, the lab evaluated the physical and mechanical properties of six different cotton-byproduct blends as a substrate for fungal colonization to manufacture the molded packaging materials. "We wanted to learn which ones met or exceeded the same characteristics of extruded polystyrene foam," says Holt.

The six proprietary recipes consisted of cottonseed hulls, gypsum, or cornstarch blended with two sizes of cotton burr particles—fine or coarse. Each blend was then inoculated with a single fungus using two different inoculation methods, grain

From Cotton Waste

ECOVATIVE (D3065-1)

Biomass packaging material made using technology developed by ARS, collaborators, and Ecovative.

and liquid, for a total of 12 treatments.

The 12 treatments were evaluated for numerous physical and mechanical properties. Overall, the treatments tested well, and the results indicated that the blend and inoculation method needed are based on the end use of the product. "The materials are water resistant, but they degrade into organic matter on sustained contact with water or soil," says Holt.

The study was published in September 2012 in the *Journal of Biobased Materials and Bioenergy*.

A Substitute for Other Products

In another project, Holt worked with a team to evaluate agricultural waste materials that can be used for recyclable, termite-resistant particleboards and pressboards and for thermoplastics (meltable at high heat), such as outdoor decking planks.

Because wood fiber is a premium product, manufacturers would like to use recyclable agricultural waste materials in place of some of the wood fiber in composite building materials. Composite boards and planks are used in nonstructural applications. Previous laboratory-scale research had shown that waste from cotton production holds great potential as a fiber filler, but the team wanted to test the products on a commercial scale.

The process of ginning seed cotton generates a significant amount of waste—as much as several million tons each year—which contains woody cotton burrs, stems, and other materials. For the study, Holt and colleagues Sreekala Bajwa and Dilpreet Bajwa, both with North Dakota State University, evaluated using cotton burrs and stems as filler. The study was supported by Cotton, Inc., and the test materials were manufactured at a Greenland Composites, Inc., facility in Greenland, Arkansas.

For the study, the team manufactured thermoplastic composite boards on a commercial scale with four different levels of added cotton burrs and stems. The four levels were 0 (controls, containing only wood fiber), 12.5, 25, and 37.5 percent by weight. The samples were tested for physical and mechanical properties that are relevant to nonstructural building applications, including water absorption, thickness swelling, thermal expansion, strength, hardness, and nail-holding capacity.

Testing showed that the commercial-scale samples they made by adding cotton burs and stems were comparable to the control boards containing only wood fiber. The study demonstrated overall that up to 12.5 percent of the wood fiber used in commercially available wood-plastic composite materials can be replaced or

This Greenland Garden Box was created from biomass using technology developed by ARS, collaborators, and Ecovative.

DILPREET BAJWA (D3062-1)

ECOVATIVE (D3063-1)

Biomass packaging material created using technology developed by ARS, collaborators, and Ecovative can be made to custom fit a wide variety of products.

supplemented by cotton burrs and stems with no significant deterioration in mechanical and physical properties that are important for all composites.

Testing of composites produced from cotton burrs and stems showed that up to 25 percent of the wood-fiber filler could be replaced without significantly increasing the composites' water-absorption and expansion performance, Holt says.

Bales That Come Wrapped

The researchers also added a different, but relatively new, agricultural waste to composites during the study. Some cotton producers are now using harvesters that make large, cylindrical bales of field-harvested cotton called "modules." The modules are wrapped in a protective film made out of low-density polyethylene. These cotton module wraps (CMWs) are removed at cotton gin facilities. If not recycled, they could become an environmental burden.

The researchers demonstrated the potential of using shredded CMWs as an ingredient in thermoplastic composites. They added up to 30 percent by weight of CMW to composite boards, as a replacement for wood-fiber filler. They showed that CMWs could replace up to 30 percent of total composite weight while maintaining the physical and mechanical properties of commercially available composites used for decking, window and door components, and landscaping products.

"We want to give ginners a way to sell their wastes for value-added applications," says Holt.

The study was published in January 2013 in *Journal of Thermoplastic Composite Material*.—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.

*Gregory A. Holt is in the USDA-ARS Cotton Production and Processing Research Unit, 1604 E. FM 1294, Lubbock, TX 79403; (806) 746-5353, greg.holt@ars.usda.gov.**

Right: A tsunami buoy is launched into the ocean from a NOAA ship. Below: ARS and Ecovative made this protective cushion, which is molded especially to fit tsunami buoys and prevent damage prior to launch by NOAA.

ECOVATIVE (D3060-1)

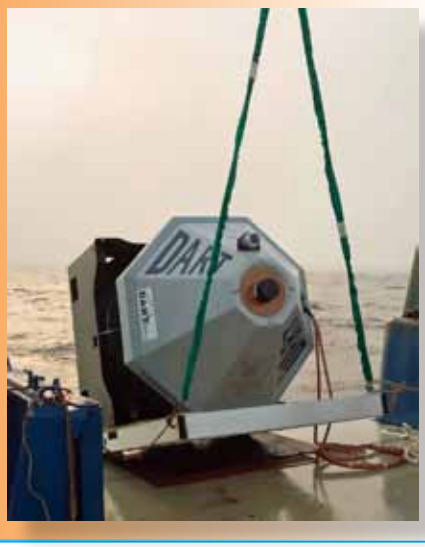
Protecting Buoys That Protect Us

The National Oceanic and Atmospheric Administration (NOAA) has introduced its next generation of tsunami-warning buoys placed at strategic locations throughout the oceans. These buoys work together to monitor and measure tsunamis in the deep ocean, forming an array. NOAA needed a moldable, biodegradable material to keep the buoys and instrumentation from getting damaged during and after launch into the ocean.

ARS scientist Greg Holt and Ecovative, based in Green Island, New York, created a biodegradable material made from a proprietary blend of biomass substrates and cotton byproducts to cushion the buoys. NOAA's Pacific Marine Environmental Laboratory based in Seattle, Washington, has successfully tested the new material in a variety of oceanic conditions and hopes to launch buoys wrapped in the protective cushioning in the near future.

The technology was developed by Ecovative with support from Holt, research leader of the ARS Cotton Production and Processing Research Unit, a division of the Cropping Systems Research Laboratory in Lubbock, Texas.—By **Rosalie Marion Bliss** and **Peggy Greb,** ARS.

NOAA (D3059-1)



Pairing Sesamol With Soybean Oil for Better Frying

STEPHEN AUSMUS (D3041-11)

ARS scientists are investigating natural antioxidant compounds that might effectively protect soybean oil from oxidation during frying. In tests with french fries, sesamol, extracted from sesame oil, proved better at this task than a commonly used synthetic antioxidant.

Whether it's spicy stir-fried vegetables from your favorite Chinese restaurant or a crisp, deep-fried chicken from your neighborhood diner, chances are good that both of these foods were prepared using soybean oil. In fact, soy oil makes up an estimated 70 to 80 percent of all cooking oil used commercially in restaurants, bakeries, and more, all across America.

Though it's generally regarded as a healthier choice than edible oils that are higher in saturated fat, soy oil's good-for-you polyunsaturated fatty acids are prone to oxidation at the high temperatures typically used for frying.

Oxidation can make the oil heavy and gummy, lead to off-flavors and odors, and cause the oil to form a messy foam during deep-frying.

These effects may combine to shorten the usable life of the oil, which, in some commercial settings, is reused until health regulations or quality problems dictate discarding it.

Though hydrogenation of the oil at the processing plant will retard oxidation, the procedure creates synthetic *trans*-fats that have been associated with increased risk of cardiovascular disease.

Agricultural Research Service chemist Hong-Sik Hwang, in collaborations with fellow chemists Erica L. Bakota, Mark A. Berhow, Jill K. Winkler-Moser, and research leader Sean X. Liu, is investigating interesting natural antioxidant compounds that might effectively and affordably protect soybean oil from oxidation during frying.

In preliminary experiments at the ARS National Center for Agricultural Utilization Research in Peoria, Illinois, Hwang and colleagues found that sesamol, extracted from sesame oil, provided better antioxidant protection for soy oil than nine other natural antioxidants that they tested.

Followup experiments pitted sesamol against a synthetic antioxidant, TBHQ (*tert*-butylhydroquinone). TBHQ is commonly added to soy cooking oil that's sold in bulk for commercial use, according to Hwang.

In tests with french fries, sesamol—added at the rate of 6,600 parts sesamol per 1 million parts soy oil—provided better protection than TBHQ added at the allowable maximum of 200 parts per million, the team found.

Two well-accepted indicators of oxidation—polymerization of certain soy oil molecules and loss of specific soy-oil protons—were used to evaluate samples of the oil throughout the 8-hour frying test.

More research is needed to ensure that using sesamol at levels that provide antioxidant protection would, at the same time, meet federal GRAS (Generally Recognized As Safe) standards. "Even a natural ingredient such as sesamol has to be evaluated for safety," Hwang notes.

The idea of pairing a sesame seed compound with soybean oil to thwart oxidation isn't new. But the Peoria group is apparently the first to investigate the concept using deep-frying tests that simulate commercial conditions.

Hwang and co-workers are now developing an approach that may enable chefs and fry cooks to automatically add sesamol to soy oil in the right amount at the right times. The tactic helps offset loss of sesamol caused by the compound's own vulnerability to oxidation at high temps. Explains Hwang, "You actually get better results if you make multiple additions of sesamol instead of just adding it all at once."

Peer-reviewed articles published in 2012 and 2013 in the *Journal of the American Oil Chemists' Society* document the research.—By **Marcia Wood,** ARS.

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

*Hong-Sik Hwang is at the USDA-ARS National Center for Agricultural Utilization Research, 1815 N. University St., Peoria, IL 61604; (309) 681-6584, hongsik.hwang@ars.usda.gov.**

Ramping Up a Phytochemical Compound in Crops

A team of Agricultural Research Service scientists has reported a biotechnological approach that enables crop species to produce, or to increase production of, the phytochemical compound pterostilbene. Stilbenes are a subgroup of phytochemicals called "polyphenols." The approach could pave the way for ramping up levels of potentially healthful pterostilbene in crops that normally produce it, such as grapes and berries.

Molecular biologists Scott R. Baerson and Zhiqiang Pan, and chemist Agnes Rimando, headed the study. They and plant physiologist Franck Dayan, a coauthor, are with the Natural Products Utilization Research Unit in Oxford, Mississippi. Also a coauthor, ARS plant pathologist James Polashock is with the Genetic Improvement of Fruits and Vegetables Lab in Beltsville, Maryland, but based in Chatsworth, New Jersey.

There are two stilbenes—resveratrol and pterostilbene—which may possess similar purported beneficial health properties. During their work, the team showed that a previously characterized and patented gene *(SbOMT3),* which they had isolated from the sorghum plant, is capable of converting resveratrol to pterostilbene. They then built on that conversion activity by co-expressing *SbOMT3* with a stilbene-synthase gene *(AhSTS3)* that had been isolated from the peanut plant. The approach was then tested in transgenic plants of two different species that do not naturally produce pterostilbene.

For the proof-of-concept study, both genes were successfully incorporated into the chromosomes of two different model host plants, *Arabidopsis* and tobacco. The two-gene strategy generated transgenic plants that were able to produce pterostilbene, the authors reported.

It is unknown whether most phytochemicals are well absorbed in the body. But based on animal-model studies conducted by other scientists, pterostilbene has significantly higher bioavailability than the parent compound resveratrol.

The study results were published in *Plant Biotechnology Journal* in 2012.

The USDA-ARS patent on the ability of *SbOMT3* to produce transgenic plants that express pterostilbene, which also describes the two-gene strategy, was issued in 2010. The ARS Office of Technology Transfer works with companies interested in obtaining required regulatory approvals, licensing ARS technologies, and conducting trials.—By **Rosalie Marion Bliss,** ARS.

Scott Baerson is in the USDA-ARS Natural Products Utilization Research Unit, P.O. Box 1157, Oxford, MS 38655; (662) 915-7965, scott.baerson@ars.usda.gov.

New, Disease-Resistant Pea Lines Developed

New garden- and dry-pea breeding lines developed by Agricultural Research Service and cooperating scientists may offer growers added insurance against outbreaks of *Aphanomyces* root rot, a disease that can cause yield losses of 20 to 100 percent in the legume crop.

The moldlike culprit, *Aphanomyces euteiches,* infects roots and underground stems of susceptible pea plants and other legumes, rotting them and causing stunted growth, lesions, wilted leaves, and other symptoms.

Currently no fungicides are registered for use with peas to control *Aphanomyces* root rot. Growers must either avoid planting in fields with a history of the disease or try rotating in nonhost crops until pathogen numbers drop to acceptable levels.

But avoidance and crop rotation may not always be economically feasible. Breeding peas for *Aphanomyces* resistance has proven difficult because multiple genes are involved. Resistance genes are also associated with undesirable traits, which cultivated varieties can inherit when crossed with wild germplasm sources, notes Rebecca McGee, a plant geneticist ARS's Grain Legume Genetics Physiology Research Unit in Pullman, Washington.

McGee, ARS geneticist Clare Coyne, and colleagues have sought to develop pea germplasm lines that can tolerate the pathogen. Coyne is with ARS's Plant Germplasm Introduction and Testing Research Unit, also in Pullman.

"We say the lines are 'highly tolerant,' or 'partially resistant,' because in severe disease conditions, even the best lines show some symptoms, though they may not have significant yield loss," explains McGee, who collaborated with scientists from ARS, New Zealand, and Europe to develop the *Aphanomyces*-tolerant lines.

The pea lines are eighth-generation descendants of an inbred population of plants derived from an ARS cross, made in 1993, between the cultivar Dark Skin Perfection and germplasm line 90-2131. In addition to their high tolerance of *Aphanomyces* root rot, the lines were also selected for their acceptable agronomic characteristics.

The breeding lines themselves aren't intended for commercial production, but rather as a source of *Aphanomyces* tolerance for incorporation into elite pea varieties. Such varieties could be welcome news for growers in Pacific Northwest and North Central states where *Aphanomyces* outbreaks threaten the valued role that peas and other legumes play in cereal-based crop rotation systems.

"Typically, cereals sown after legumes, especially peas and lentils, yield more than cereal-following-cereal plantings," notes McGee. "But if *Aphanomyces* root rot is severe, pea crop losses can be 100 percent."

In addition to releasing *Aphanomyces*-tolerant material, the scientists are working to make DNA markers that breeders can use in their programs, McGee says.—By **Jan Suszkiw,** ARS.

Rebecca McGee is in the USDA-ARS Grain Legume Genetics Physiology Research Unit, Washington State University, Johnson Hall, Pullman, WA 99164-6434; (509) 335-0300, rebecca.mcgee@ars.usda.gov.

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

Pullman, Washington
6 research units ■ 136 employees

Northwest Irrigation and Soils Research Laboratory, Kimberly, Idaho
1 research unit ■ 40 employees

Cropping Systems Research Laboratory, Lubbock, Texas
4 research units ■ 113 employees

Northern Great Plains Research Laboratory, Mandan, North Dakota
1 research unit ■ 47 employees

North Central Soil Conservation Research Laboratory, Morris, Minnesota
1 research unit ■ 27 employees

Little Rock, Arkansas
ARS funds cooperative research at this location.

National Center for Agricultural Utilization Research, Peoria, Illinois
7 research units ■ 226 employees

Jamie Whitten Delta States Research Center, Stoneville, Mississippi
7 research units ■ 260 employees

Oxford, Mississippi
3 research units ■ 102 employees

Animal Waste Management Research Unit, Bowling Green, Kentucky
1 research unit ■ 16 employees

Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, Florida
4 research units ■ 134 employees

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

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YAGUANG LUO (D3067-2)

Inside Next Online Issue

Spotlight On ...

Podcast on Research at Plum Island

ARS researchers at Plum Island Animal Disease Center are guarding the country against foreign animal diseases. To view a short podcast on some of the research at the center, visit ars.usda.gov/is/podcasts/island.htm

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