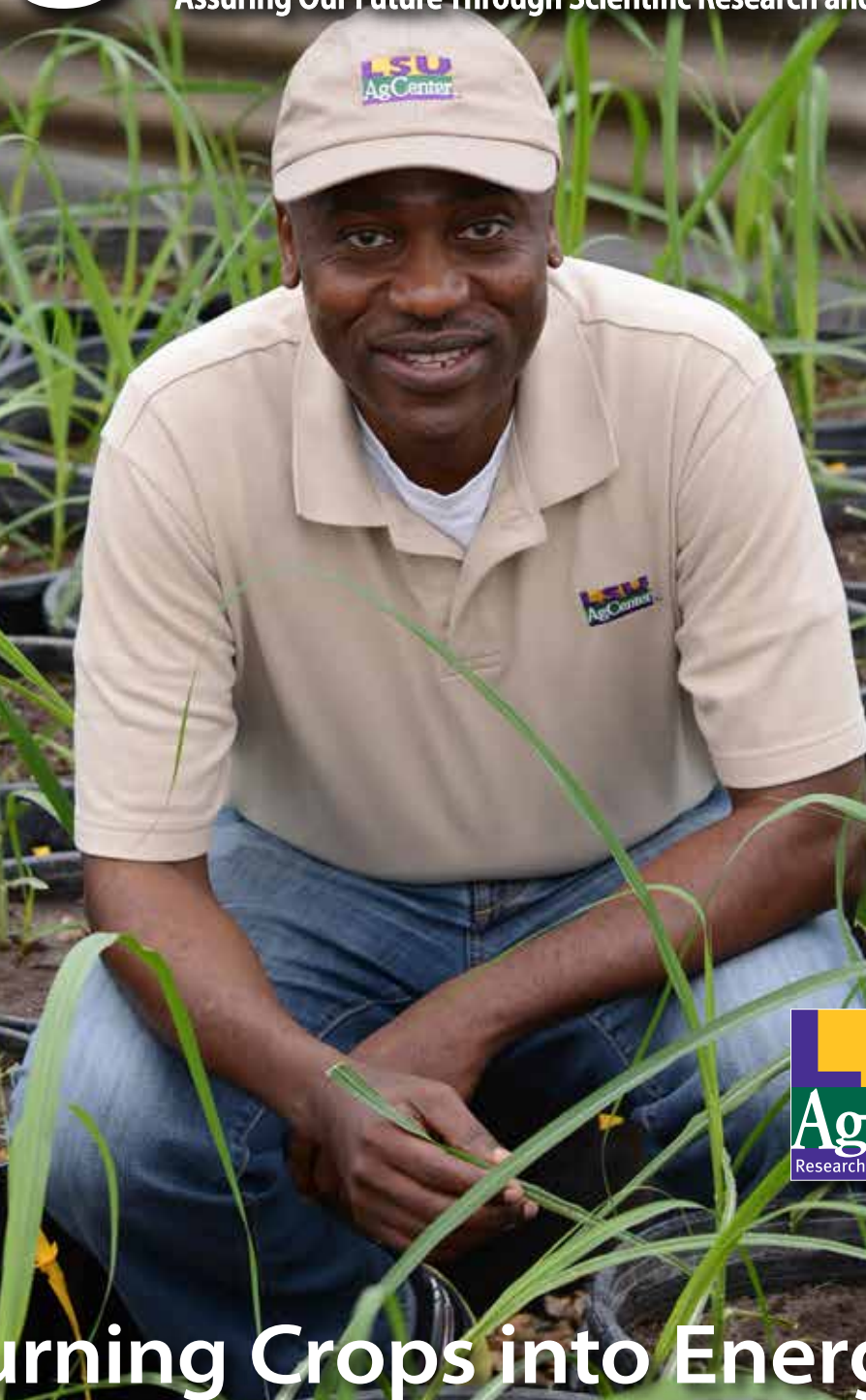


LOUISIANA Agriculture

Assuring Our Future Through Scientific Research and Education

Vol. 58, No. 2, Spring 2015
Published Since 1957



Turning Crops into Energy

New Crops for Biofuel Production in Louisiana

Donal F. Day

In 2011, the LSU AgCenter embarked upon a five-year initiative, funded through the U.S. Department of Agriculture, to develop crops that can be used for biofuel production across the southern United States, thus offering an opportunity to improve local farm incomes, create manufacturing jobs and supply significant quantities of feedstocks for the next generation biofuel industries. The major constraints on the chosen crops are the ability to tolerate the wide variety of climatic conditions that exist between north and south Louisiana and the need for staggered harvest schedules so crops can be delivered continuously to processing facilities over a major portion of a year.

To take advantage of Louisiana's experience in sugarcane production and processing, two crops similar in structure to sugarcane and containing fermentable sugars – energycane and sweet sorghum – were chosen for development. Energycane is a variant of sugarcane high in fiber and low in sugar-containing juice. Sweet sorghum, a relative of grain sorghum that produces less seed, also contains a sugar juice. Both crops can be harvested and processed in a manner similar to sugarcane. The fermentable sugars in these juices could support rapid development for biofuel or any fermentation-based bioproducts industry, with lignocellulosic sugars phasing in as conversion technologies develop. The two chosen crops appear to be productive on marginal or underutilized land and would not affect current crop production.

Energycane will produce 20 dry tons per acre of biomass and 24 tons of juice per acre. The juice contains about 4,700 pounds of sugars per acre, primarily sucrose. The composition of sugars in the juice is identical to that of sugarcane juice. The biomass component again looks like sugarcane in composition. The major difference from commercial sugarcane is in the biomass-to-juice ratio, with energycane producing significantly more biomass and less juice than commercial sugarcane. This crop grows significantly faster than commercial sugarcane. Because of fast growth, it outcompetes weeds for water and light, negating the need for herbicide treatment. Most importantly, this crop survives winters in north Louisiana.

Sweet sorghum is in many ways the opposite of energycane. It produces more juice and less biomass. The juice contains sucrose, glucose and fructose. The yields per acre are less than energycane, 5-10 dry tons of biomass per acre and 3.6-36 tons of juice per acre, containing between 600 to 6,000 pounds of sugar per acre. Unlike energycane, it is an annual with a short growing season, 90-120 days, depending on the variety, allowing rotation with a nitrogen-fixing crop, such as clover, to minimize fertilizer requirements. The harvest cycle covers a part of the year when energycane is not available.

Post-harvest processing of these crops using sugarcane processing technology produces biomass and sugar syrups that are storable and contain high contents of fermentables. The biomass is suitable for power generation and could be converted to fermentable sugars using technologies that have been developed for converting corn biomass, called stover, to fermentable sugars. The value of these syrup sugars should be competitive with the value of sugars in sugarcane molasses. The breeding programs at the LSU AgCenter and the USDA Agricultural Research Service-Sugarcane Research Unit in Houma are producing improved varieties of energycane that give higher yields and show improved cold resistance. Commercial varieties of sweet sorghum are already available.

Markets have yet to be established for products from these crops. The syrups should fit well into the molasses markets, but there is not yet an established market for the biomass. Growth of industries that can use these crops will provide a path for financial growth for underdeveloped agricultural regions in Louisiana.

Donal F. Day is a professor and researcher at the Audubon Sugar Institute in St. Gabriel.



Harvesting sweet sorghum at the Sugar Research Station in St. Gabriel. Photo by A. Denise Attaway

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Louisiana Agriculture is published quarterly by the Louisiana Agricultural Experiment Station. Subscriptions are free. You may also subscribe to a Web version of the magazine, which is available at www.LSUAgCenter.com. Please go to the "Louisiana Agriculture Magazine" site if you would like to receive an email notification when a new issue is online. If you would like to download the magazine to your e-reader, go to the magazine's website, choose the correct format, and follow the directions on your mobile device. For more information or to subscribe, please contact:

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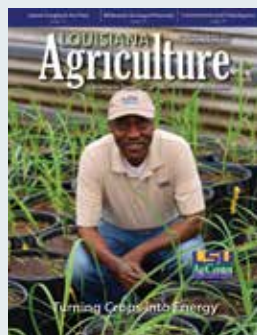
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ON THE COVER: Collins Kimbeng, a plant breeder with the LSU AgCenter, is involved with developing high-biomass, low-sugar varieties of sugarcane, known as energycane, and expanding the area of production of these new varieties north of the traditional sugarcane-growing belt in south Louisiana. Energycane varieties, derived by crossbreeding sugarcane with its wild relatives, are raised in greenhouses until they are planted in fields across the state for evaluation. Kimbeng and other researchers are studying ways to improve cold tolerance of energycane varieties, including fertility management for northern locations, harvest time effects on feedstock quality and planting methods. Photo by John Wozniak

Thousands of students participate in Wetlands Week



Terry Barker, at left, an elementary education major at LSU of Alexandria, gives students a closer look at some insects they found during a scavenger hunt at Wetlands Exploration Day at 4-H Camp Grant on April 23. Photo by Brandy Orlando

Thousands of students from across the state participated in various events during Wetlands Week April 20-24 to celebrate Louisiana's most valuable treasure. At 4-H Camp Grant Walker in Pollock, the event was called Wetlands Exploration Day, and it was April 23, said Ashley Powell, camp coordinator.

"It's a great opportunity for the kids to take science outdoors," she said.

Thirty fifth-graders from Colfax Elementary School in Colfax, Louisiana, rotated through five learning tracks: An Arthropod Adventure, Investigating Insects, Wetlands Taste Exploration, You Are What You Beak and Birds of a Feather.

Begun in 2007, the 4-H Youth Wetlands Program is funded by a grant through the Coastal Protection and Restoration Authority. The program offers teachers in grades three through 12 a free, 35-lesson curriculum tying wetlands into Louisiana Grade Level Expectations, according to Ashley Mullens, the director. **Brandy Orlando**

\$250,000 grant to fund foam insulation research

The LSU AgCenter has received a \$250,000 grant from the U.S. Department of Agriculture's Innovative Uses of Wood program. The grant will fund a project on biobased spray foam insulation from wood residues. The project is led by forest products researchers Todd Shupe and Niels de Hoop from the School of Renewable Natural Resources.

"The main goal of the project is to determine the potential of low-value wood fiber as a raw material for the development of a green spray foam insulation," Shupe said. "Consumers are demanding green products for their houses, but insulation is one product that is currently not very green."

This project will allow the team to determine the potential of small-diameter timber and low-value fiber as a feedstock for spray foam insulation. This material currently has little to no value but poses a significant risk for wildfires, Shupe said.

In addition to substantial energy cost savings, wood-based spray foam has much better biodegradability compared to petroleum-based foam insulation, which will benefit the environment when this material is landfilled. **Johnny Morgan**



Examples of wood-based foam samples produced by the LSU AgCenter during preliminary research. Photo by Todd Shupe

Improving deer health topic for field day

Owners of high-fence deer facilities and others interested in the business attended the high fence deer management field day at the LSU AgCenter Bob R. Jones Wildlife Institute, in Clinton, Louisiana, on April 22.

Glen Gentry, interim director at the AgCenter Bob R. Jones Idlewild Research Station, said there are a number of high-fence operations in Louisiana, with most of the larger operations in the northern part of the state. There are also breeder pens that feed the larger high-fence hunting operations.

The sizes range from 30 to 40 acres for the breeder pens to 500 to 2,500 acres for the hunting operations, Gentry said.

"One of the goals of the breeders is to improve the genetics of the deer in their herds, which normally means larger antler size," said Phil Elzer, LSU AgCenter associate vice chancellor and program leader for animal sciences. They also are looking for animals with resistance to disease so they can be sold to others in the business.

Johnny Morgan

Food Incubator receives \$2.5 million grant

The LSU AgCenter Food Incubator has received a three-year \$2.5 million grant from the Louisiana Office of Community Development's Disaster Recovery Unit. The grant comes from federal Community Development Block Grant Funds provided to the state by the U.S. Department of Housing and Urban Development to stimulate economic development in areas of the state affected by hurricanes Gustav and Ike in 2008.

The Food Incubator, which was established in 2013 and currently serves 25 tenants, provides food entrepreneurs tools and expertise to test, produce, package and market foods. The grant will allow purchase of more equipment so that about 200 clients can be accommodated in some capacity.

A number of tenants are now selling their products, which range from salad dressings to snack foods, in regional locations of Whole Foods, Fresh Market, Associated Grocers stores and Rouses Supermarkets.

"The continued success of the food companies is due to the LSU AgCenter's resources, equipment, support staff and our network within the community," said Gaye Sandoz, director. **Olivia McClure**

Researchers share tips for wheat, oats at field day

Dozens of wheat and oat varieties from university research and commercial companies were on display at the annual wheat and oat field day at the LSU AgCenter Macon Ridge Research Station, in Winnsboro, on April 22.



LSU AgCenter plant breeder Steve Harrison, left, explains differences among oat varieties to visitors at the wheat and oat field day on April 22 at the Macon Ridge Research Station. Photo by Rick Bogren

Stripe rust, freeze damage and driving rains were a combination that created problems this year for farmers, said Steve Harrison, AgCenter small grains breeder.

Scab disease problems are growth-stage dependent, Harrison said. "We have to work on scab from a genetics perspective and from a management perspective."

AgCenter plant pathologist Trey Price reviewed research trials that screen varieties for resistance to scab, which is also known as fusarium head blight. The fungus also causes ear rot, stalk rot and root rot in corn.

Price rates all plots to identify resistance in different varieties. He suggested staggered planting so all the crop doesn't mature at the same time, avoiding a total infestation of scab disease. Maximum control from fungicides is about 50 percent and average control is about 40 percent, Price said. "Fungicide application is effective during a five-day window, so timing and coverage are critical." **Rick Bogren**

Master Farmer Program receives award



The Louisiana Master Farmer Program received the Conservation Educator of the Year Award at the 51st Governor's State Conservation Achievement Awards Program, hosted by Louisiana Wildlife Federation. Left to right are James Hendrix, LSU AgCenter agent; Robert Barham, Louisiana Department of Wildlife and Fisheries secretary; Ernest Girouard, Master Farmer coordinator; Allen Hogan and Donna Morgan, LSU AgCenter agents; and Barney Callahan, LWF president. Photo by Teri Henry/Louisiana Wildlife Federation

The Louisiana Master Farmer Program was honored by the Louisiana Wildlife Federation at the Governor's State Conservation Achievement Award Banquet on March 28.

Receiving the Louisiana Wildlife Federation Conservation Educator of the Year Award were Louisiana Master Farmer Program Coordinator Ernest Girouard and team members Donna Morgan, Allen Hogan and James Hendrix, all AgCenter extension agents.

"It's recognition of the work we do in helping farmers adopt the environmental and conservation practices that protect Louisiana's natural resources," Girouard said. "It's great to be recognized for the conservation effort with farmers in our state."

Girouard said the program is unique because it involves a partnership of the LSU AgCenter, Louisiana Department of Agriculture and Forestry, Natural Resources Conservation Service, Louisiana Cattlemen's Association and the Louisiana Farm Bureau.

To date, more than 200 Louisiana farmers have achieved full Master Farmer certification. An additional 2,496 farmers are enrolled in the program and currently undertaking various phases of the educational and conservation plan implementation process. **Bruce Schultz**

Lafayette Parish teacher honored for ag education

Judy Morgan, fourth-grade teacher at Charles Burke Elementary School in Lafayette Parish, has been honored by the Louisiana Farm Bureau as Ag in the Classroom Teacher of the Year for her school garden project.

Along with the award came a \$600 grant from the Farm Bureau to help pay for improvements to the garden.

"I was stunned," Morgan said.

The award was affirmation that the 4-H school garden is a huge benefit to her class, Morgan said. She is coordinator of the LSU AgCenter 4-H School Garden Initiative Program at Charles Burke Elementary School. She said the AgCenter expertise has been essential to the garden's success.

The entire AgCenter faculty is supportive, she said. "I can call any one person, and they respond."

Four fourth-grade classes, about 80 students, participate in the school's garden program.

The Farm Bureau Ag in the Classroom program is designed to help students gain an awareness of the role agriculture plays in the economy and society. The program also helps teachers use agriculture in their curriculum. **Bruce Schultz**



Teacher Judy Morgan shows one of her students a weed to be pulled from vegetable seedlings at Charles Burke Elementary School in Lafayette Parish. Photo by Bruce Schultz

7 students spend spring break in Nicaragua

Many college students like to spend spring break somewhere tropical. That is what a group of seven LSU College of Agriculture students did on their spring break, April 4-11. But this group wasn't lounging on beaches. The students were visiting coffee, tobacco and rice farms, learning about the entire production process for each crop.

Ivana Tregenza, director of international relations for the LSU College of Agriculture and program coordinator for the LSU AgCenter International Programs office, said a student's career preparation is not complete without international experience and some knowledge of global issues.



A group of LSU College of Agriculture students visited Volcano Masaya in Nicaragua during spring break. The students included, left to right, Shelli Danjean, Cristina Serrano, Bradley Coleman, Chelsea Sutherland, Myra Boudreaux, Emily Klaus and Peyton Beattie. Ivana Tregenza, far right, is the director of international relations for the LSU College of Agriculture and program coordinator for the LSU AgCenter International Programs office. Photo provided by Cristina Serrano

Bradley Coleman, a senior in agricultural education, from Ponchatoula, Louisiana, has traveled abroad. Coleman plans to teach after graduation and said his experiences will help make him a more valuable teacher.

"I can share these experiences with my students and maybe encourage or arrange for students to travel abroad," Coleman said.

On their last day in Nicaragua the students visited a market and purchased and delivered food to underprivileged families. They also worked in an aftercare program with young children.

All of the students expressed how their time in Nicaragua gave them a new perspective on agriculture and the world.

"You can't get these experiences any other way than going abroad," said Myra Boudreaux, a junior studying agricultural education from Belle Rose, Louisiana.

Tobie Blanchard

Alumni Association presents annual awards

The LSU College of Agriculture Alumni Association recognized outstanding alumni, faculty and students at a ceremony on April 24.

Two people received the outstanding alumni award. They are Dorothy Howell, of Baton Rouge, who is a 1942 and 1944 graduate with degrees in home economics, and Milton Reese, of Gueydan, Louisiana, a 1969 graduate with a degree in agribusiness.

Howell was instrumental in the publication of the "Tiger Bait Cookbook," proceeds from which contributed to more than 125 scholarships for College of Ag students.

Reese is president of Milton Reese and Associates, LLC, which engages in railroad and transportation consulting, property management and farm production management.

The early career outstanding alumni award went to Mike Kaller, who received his doctorate in fisheries and wildlife management from the College of Ag in 2005. He joined the college's School of Renewable Natural Resources as an assistant professor in 2007.

Kayanush Aryana, professor in dairy foods technology, received the Alumni Association excellence in teaching award. Aryana was recognized for mentoring undergraduates with research projects and advising graduate students.

Jamie Boudreaux, a senior with a double major in animal, dairy and poultry sciences and in agricultural education, from Donaldsonville, Louisiana, received the Gerald and Norma Dill Outstanding Senior Award.

Anna Claire Ferchaud, a senior majoring in natural resources ecology and management, from West Monroe, Louisiana, received the K.C. Toups Memorial Les Voyageurs Award. **Tobie Blanchard**



Dorothy Howell, of Baton Rouge, pictured with her granddaughter, Shannon Han-naman, received the outstanding alumni award from the LSU College of Agriculture Alumni Association. Howell, a 1942 and 1944 graduate, has degrees in home economics. Photo by Tobie Blanchard

LSU sports dietitian heads to big leagues



Jamie Meeks prepared for a career in sports nutrition through studies in the LSU College of Agriculture's food and nutrition sciences program. Photo by Tobie Blanchard

After four years of helping college athletes stay healthy, Jamie Meeks is going pro. The registered dietitian and alumna of the LSU College of Agriculture's School of Nutrition and Food Sciences has been named the director of sports nutrition for the New Orleans Saints and New Orleans Pelicans. Meeks directed LSU's athletic nutrition program before joining the Saints and Pelicans.

"I think the role will be similar, but now that these athletes have made it to the big league, my job is to help them stay there," Meeks said. "I'll be doing a lot of education on how to keep their bodies healthy and also prevent injury."

Meeks became interested in pursuing a career in nutrition after visiting a dietitian in high school. Meeks was preparing to try out for the LSU cheerleading squad and said she had some misconceptions about how to eat healthfully. Meeks made the team and cheered for LSU for four years. During that time she knew her passion was in sports nutrition.

"I wanted to help athletes become the best athletes they can be," she said. "The way they eat is just as important as practice on the field, workouts in the weight room, rehab and treatment in the training room."

Meeks said the LSU College of Agriculture's food and nutrition sciences program prepared her for her profession.

"Everything I learned in my dietetics program as an undergrad I do now with my job as a sports dietitian," Meeks said.

Tobie Blanchard

Students look at fish diversity by 'electrofishing'

With Lake Maurepas standing in for their classroom, LSU College of Agriculture students in the School of Renewable Natural Resources boarded a boat equipped with a generator and anodes. The anodes send electrical currents through the water to temporarily stun fish.

The students were "electrofishing," which is used to sample fish populations.

Matthew Repp, a senior from Vermilion Parish studying natural resource ecology and management, was in the first group of students to go out on the water.

"We did a type of method where we would continually shock and move through an area so we could get a variety of fish," Repp said.

The students netted fish that came to the surface and brought their catches to shore to be identified and counted.

Associate professor Mike Kaller teaches the course, which covers quantitative techniques in habitat, water quality and fish population assessment in freshwater ecosystems. The class features hands-on activities that help the students learn the skills of their professions.

Electrofishing is a common scientific survey method and does not permanently harm the fish. **Tobie Blanchard**



LSU College of Agriculture students Morgan Ducote and William Budnick seine for fish at a boat launch on Lake Maurepas while their classmates electrofish on the lake. Associate professor Mike Kaller (left) looks on with other students. Photo by Tobie Blanchard

Faculty, students awarded professorships, assistantships

Three faculty members and two graduate students in the LSU AgCenter and College of Agriculture have received financial awards to carry out research.

Faculty members Jeanna Kuttruff, Dan Fromme and Brenda Tubaña were named to endowed professorships. Graduate students Lina Bernaoli and Ben McInnes received assistantships.

Bill Richardson, LSU vice president for agriculture and dean of the College of Agriculture, said it is through the generosity, loyalty and oftentimes an opportunity to pay it forward that alumni and friends choose to create a professorship.

"A professorship provides perpetual support for outstanding faculty members and enables them to pursue research and innovative teaching methods," Richardson said.

Head of the Department of Textiles, Apparel Design and Merchandising, Kuttruff was named the Beverly Griffin Shea Alumni Association Departmental Professor. Kuttruff's research has focused on historical textiles such as Acadian dress and 19th century burial garments.

Fromme, an associate professor with the LSU AgCenter, was named the Tom and Martha Burch and Delta & Pine Land Company Professor. Fromme is the state cotton and corn specialist.

Tubaña, an associate professor in the School of Plant, Environmental

and Soil Sciences, was named the Jack E. and Henrietta Jones Professor. Tubaña's area of specialization is soil fertility and nutrient management for major row crops grown in Louisiana.

Lina Bernaoli, a graduate student in the Department of Entomology, received the Ray and Dorothy Young Endowed Assistantship in Louisiana Row Crop Integrated Pest Management. Bernaoli studies the effects of mycorrhizal fungi, a symbiotic, soil-borne organism, on rice resistance to insect herbivores and pathogens.

Ben McInnes, a graduate student in the Department of Plant Pathology, received the DuPont Crop Protection assistantship. McInnes' research focuses on nematology, and his long-term goal is to work for an agricultural chemical company. **Tobie Blanchard**



Lina Bernaoli, center, a graduate student in the LSU Department of Entomology, received the Ray and Dorothy Young Endowed Assistantship in Louisiana Row Crop Integrated Pest Management. Ray and Dorothy Young have been active in Louisiana's cotton industry for more than 50 years. Photo by Tobie Blanchard

Students get hands-on training in poultry program

The chirping of baby chicks rang through a poultry lab on LSU's campus. LSU AgCenter poultry specialist Theresia Lavergne had a research associate and graduate and undergraduate students helping her sort, weigh and band the birds for a research project.

The poultry science program is a small but valuable part of the LSU College of Agriculture's School of Animal Sciences. Students in the program can get hands-on experiences with birds in their classes and as student workers or volunteers in labs.

"They learn how to feed it, how to make sure it has water at all times, to collect data, so they actually get experience raising birds," Lavergne said.

LSU's poultry science curriculum includes poultry grading and evaluation, incubating and hatching, poultry biology and management classes.

Students can get experience working with birds in research projects on campus like the one Lavergne was conducting on nutrition. Students also can lead their own research projects. **Tobie Blanchard**



Elizabeth Fudge, freshman, and Andrea Rubio, a visiting scholar from Zamorano University in Honduras, help band birds for a research project that Theresia Lavergne, LSU AgCenter poultry specialist, is conducting on poultry nutrition. Photo by Tobie Blanchard



The LSU AgCenter biofuels pilot plant, located Audubon Sugar Institute at St. Gabriel, is a premier facility for processing energycane, sweet sorghum and other grassy feedstocks into convertible sugars, fiber and bioproducts for further refining into butanol, gasoline, isoprene and other biochemicals. John Russin, AgCenter vice chancellor, oversees the biofuels and bioproducts project. Photo by John Wozniak

Overview and Perspective

Biofuels and Bioprocessing in Louisiana

John Russin

Louisiana has long been recognized for oil and gas production. From the first producing oil well in Jennings in 1901 and the first natural gas pipeline near Shreveport in 1908, our state has matured into a globally recognized hub for recovery, processing and transportation of fossil-based fuels, chemicals and specialty products. Over the years, Louisiana has drilled more than 1 million producing wells that have yielded billions of barrels of oil and trillions of cubic feet of natural gas. Trailing only Texas, Alaska and California in crude oil production, Louisiana produces nearly 23 percent of our nation's crude oil and nearly 11 percent of the nation's natural gas. Not surprisingly, the oil and gas sector remains a principal economic driver in Louisiana and across the Gulf of Mexico region.

However, worldwide dependence on these nonrenewable fossil fuels, coupled with concerns surrounding climate change, has driven interest in alternative, renewable, biobased sources for fuels, fibers, polymers and specialty chemicals. This emerging paradigm shift from exclusive emphasis on fossil-based hydrocarbons toward expanded use of plant-based carbohydrates has created unique challenges. Many acknowledge that long-term success of these evolving industries will depend upon a balance between food needs and fuels, fuel components and specialty chemicals, but so far there have been amazing successes. Industry sources report more than 300 types of bioplastics produced currently from plant starches, including many familiar items such as shopping bags, drink bottles and dining utensils. Demand for such bioplastics is expected to increase 19 percent annually and to exceed 2 billion pounds by 2017. Clearly, this value-added market represents a great opportunity for Louisiana farmers.

The LSU AgCenter stepped into this arena in 2009 with the creation of the Louisiana Institute for Biofuels and Bioprocessing, and

in 2010 this concerted group of scientists and industry partners was awarded the single largest grant in LSU AgCenter history – a \$17.2 million project from the U.S. Department of Agriculture National Institute of Food and Agriculture titled “A Regional Program for Production of Multiple Agricultural Feedstocks and Processing to Biofuels and Biobased Chemicals.” The main goal of this five-year project is to expand the agricultural sector in the Southern region by developing production and utilization systems for ‘dedicated energy crops’ that USDA had determined were optimal for our region – energycane and sweet sorghum. The project encompasses four main objectives:

- Evaluation and improvement of energy crops for sustainable production in low-input marginal systems.
- Development of pilot and industrial facilities for syrup and bio-mass production that will support fuel and specialty chemical production.
- Finding regionally appropriate business, logistic and supply chain models.
- Education initiatives to support practical training for students, supply chain participants and the general public.

The first challenge in this effort was to develop production guidelines for energycane and sweet sorghum. While Louisiana and other states already developed optimal production systems for sugarcane (low fiber, high sugar), the focus for energycane was opposite (high fiber, low sugar). Existing selection and breeding programs in cane required rapid expansion to accommodate this new crop while not sacrificing existing efforts on commercial sugarcane varieties. Our close partnership with the U.S. Department of Agriculture-Agricultural Research Service Sugarcane Research Unit in Houma,

Louisiana, has helped greatly in this effort. Their existing body of work on energycane varieties provided a strong foundation upon which our joint efforts could build. Efforts with sweet sorghum were aided greatly by a key industry partner Ceres Corporation, an agricultural biotech company in Thousand Oaks, California, that develops and markets crops for bioenergy and other uses and prior support through the Sun Grant Initiative, a national network of land-grant universities and federally funded laboratories working together to further establish a biobased economy. The AgCenter is well on its way to developing reliable guidelines to sustainably produce, manage and harvest these new crops on traditional and marginal lands in our state and across the South.

Design and manufacture of a versatile pilot-scale facility posed significant challenges. Unlike the designated energy crops from other regions of the United States (primarily dried wood and grassy crops), those designated for Louisiana were unique in that they contained two distinct feedstock streams – traditional dried bagasse and sugar syrups – which required unique facilities for plant grinding, biomass storage and syrup preparation. This one-of-a-kind facility has been installed at our Audubon Sugar Institute and is entering its final phases of facility optimization prior to use. An added bonus is that this pilot facility also can support the AgCenter's traditional sugar processing research programs. At present, the first batch of purified syrups from Louisiana energy crops is being prepared for delivery to Virent Inc., of Madison, Wisconsin, which will use these as feedstocks in their proprietary processes for fuel and specialty chemical production.

Biomass crops targeted for other regions of our country will be subject to a single harvest, then baled and stored until used – a supply chain that has very simple logistics. Harvest and processing of energycane and sweet sorghum posed distinctive challenges because of the staggered harvest of these fresh crops throughout the year. Efforts to develop more complicated logistics and supply chain models for our crops were aided by considering the sugarcane industry. Guided by existing models for harvest, transport and processing logistics for sugarcane, scientists on this project are developing similar guidelines for both energycane and sweet sorghum. This will involve geographic regions far beyond the traditional sugarcane



Energycane grown at the LSU AgCenter Sugar Research Station in St. Gabriel is harvested and transported with machinery used for commercial sugarcane. This existing machinery can be used without modification for both energycane and sweet sorghum. Energycane is a high-fiber, low-sugar-content sugarcane grown for use as a feedstock for biofuels. Photo by A. Denise Attaway

production areas, as both crops have notably greater cold tolerance. Challenges also arose in our efforts to identify suitable lands for energy crop production that do not impact traditional food and fiber crops. These efforts have identified more than 12 million acres in our region that are classified by USDA as marginal lands, which generally are more erodible, droughty and less productive and cannot be easily cultivated, making them potentially suitable for these low-input biomass crops.

Our studies have identified a number of surprising advantages that biomass crop cultivation can provide. We have learned that harvest and transport machinery used currently for commercial sugarcane can be used without modification for either energycane or sweet sorghum. Studies showed also that these crops can produce sustained yields in the absence of large amounts of chemical fertilizer, particularly if alternated with a clover crop. Both crops, but especially energycane, produce a very dense, tight canopy that effectively shades out most weeds, thereby reducing the need for herbicides. And few insect or pathogen pests have developed in plots thus far which suggests that pest control inputs may be minimal. According to our analyses, an additional environmental benefit comes in the form of a smaller carbon footprint for both energycane and sweet sorghum compared to conventional crops. Together, these environmental benefits could provide a significant boost to interest in these crops.

Existing food and fiber crops enjoy high levels of public recognition and acceptance that are absent for these biomass crops. Unfortunately, a myriad of editorial cartoons have enthusiastically – but unrealistically – depicted biofuels as imminent, ubiquitous and readily produced through the most rudimentary means. These circumstances highlight the need for a rigorous, multifaceted, science-based education program for stakeholders at every level. Extension and communication experts are addressing this challenge on many fronts. For example, definitive production guidelines are being developed for energycane and sweet sorghum, so that Southern farmers are equipped with necessary information for cropping decisions. New university-level courses will train scientists on practical aspects of biomass crop production and processing. Age-appropriate materials are being developed that will introduce these topics to pre-K and elementary students and engage older students with projects and activities. And public education will continue as we learn more about the practicalities and possibilities of biomass crop production as part of the Louisiana agricultural landscape.

John Russin is the vice chancellor of the LSU AgCenter.



Sweet sorghum is grown and studied for use as a biofuel feedstock at the LSU AgCenter Sugar Research Station in St. Gabriel. Sweet sorghum is an annual crop, and plants can reach heights of 12 to 14 feet. It can be planted and managed using the same equipment typically used in row crop production. It can be processed (juice extracted) through processes used for sugarcane. The bagasse (fiber) that remains after milling is suitable for use as a lignocellulose feedstock in biochemical or advanced biofuel production. Bagasse also is suitable to use as fuel for operation of the mills. Sugar yield is the most important aspect of sweet sorghum on which to base management decisions for potential use in the emerging biochemical/biofuel industry. Photo by A. Denise Attaway

Developing Energycane Varieties for the Bioenergy and Bioproducts Industry

Collins Kimbeng, Niranjan Baisakh, Anna Hale, Kaitlin Barrios and Shyue Lu

Political, environmental and economic concerns have motivated nations to become increasingly interested in renewable sources of energy and bioproducts, such as those obtained from plant biomass. With a reputation as one of the most efficient crops in converting solar energy into chemical energy, sugarcane is being considered as a feedstock to fuel this fledgling bioenergy-bioproduct industry. LSU AgCenter researchers – partnering with researchers from private and public institutions including the U.S. Department of Agriculture-Agricultural Research Service in Houma, Louisiana – are in the forefront of developing genetically improved sugarcane varieties called energycane for this industry. The objective is to develop energycane varieties that can grow beyond the boundaries of the traditional sugarcane belt with optimum biomass yields and minimal inputs.

The idea of using sugarcane to generate energy is not new. Bagasse, the residue remaining after milling sugarcane to extract sucrose, is a principal source of energy used to power the milling process. Bagasse is burned to generate steam that powers the sugar mill, and in some instances, the excess electricity produced is sold to the electric grid. In Brazil, as a matter of public policy, sugarcane juice from the milling operation is used to produce ethanol, which is blended with gasoline and used as a transportation fuel. In the U.S., corn grain is used as the primary feedstock for ethanol production.

What is new, however, is the renewed objective of both the U.S. Department of Energy and USDA to replace a percentage of the current U.S. petroleum consumption with biofuels. This effort is expected to support the growth of agriculture in rural economies and foster new domestic industries such as biorefineries to produce a variety of fuels, chemicals and other bioproducts. Also new is the food-versus-fuel debate, which has brought

into sharper focus the need to plant dedicated energy crops, such as energycane, in areas that will not compete with food crops.

The term energycane is used loosely to describe derivatives of sugarcane bred specifically as an energy crop. Recent energycane varieties have been developed by crossing cultivated sugarcane with its wild relative *Saccharum spontaneum* or the allied species *Miscanthus*. These crosses take advantage of traits such as biomass yield; tolerance to stresses from diseases, insect pests, drought and cold weather (Figure 2); and the ability to regrow after harvest without replanting. Selection in the resulting progeny focuses on maximizing biomass rather than sugar yield. Compared with sugarcane, energycane varieties are usually higher in biomass yield and fiber content and lower in sucrose content. The resulting feedstock used for bioprocessing is the lignocellulosic biomass.

AgCenter researchers, collaborating with scientists from the USDA-ARS in Houma, planted approximately 1,000 experimental varieties of energycane at the LSU AgCenter Macon Ridge Research Station in Winnsboro in 2012. These experimental varieties came from crosses specifically designed to maximize traits other than sucrose content, such as biomass yield, biomass quality and stress tolerance. Evaluating these experimental energycane varieties in Winnsboro, which is well outside of the traditional sugarcane belt, provides a challenging environment and the opportunity to select varieties that expand the geographical range of cultivation of energycane (Figure 1). Unlike traditional crops grown in this region, the energycane crop received no irrigation throughout its growth cycle. A sample of about 300 varieties that continued to show desirable characteristics was selected and replanted in 2013. Data collected so far, including the exposure of these experimental varieties in late

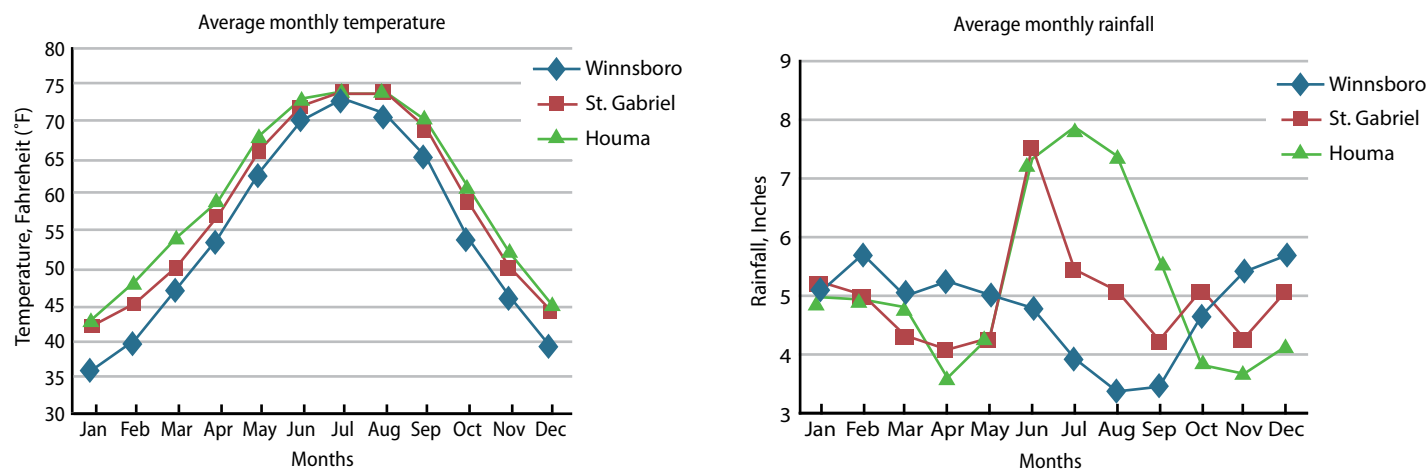


Figure 1. Average monthly temperatures (°F) and rainfall (inches) in Winnsboro, St. Gabriel and Houma, Louisiana. Note the differences in temperature and rainfall pattern between Winnsboro and the other two locations found within the sugarcane belt. Source: Weather Channel, LLC.

Collins Kimbeng is a professor at the Sugar Research Station in St. Gabriel. Niranjan Baisakh is an associate professor, School of Plant, Environmental and Soil Sciences. Anna Hale is a research geneticist, Sugarcane Research Unit, USDA-ARS, Houma. Kaitlin Barrios is a research associate at the Sugar Research Station, and Shyue Lu is a research associate at the Audubon Sugar Institute, St. Gabriel.

... *energycane varieties that can grow beyond the boundaries of the traditional sugarcane belt with optimum biomass yields and minimal inputs.*

2013 to one of the coldest winters recorded in Louisiana, suggest a great potential for some of these varieties to be adapted for growth in colder climates outside of the traditional sugarcane-growing regions.

The ability of some energycane varieties to survive and thrive under very cold conditions in Louisiana presented AgCenter scientists with the opportunity to identify genes responsible for imparting cold tolerance. A number of cold-responsive genes have been isolated and characterized from an energycane variety. Genetic markers derived from these genes were used to distinguish among cold-sensitive commercial sugarcane hybrids, cold-tolerant *Saccharum spontaneum* and energycane clones. Further genetic mapping studies have led to the identification of several quantitative trait loci or genomic regions that contribute to different biomass and cold-tolerance traits. Ongoing efforts to identify genetic markers linked to these traits will facilitate the rapid screening and development of genetically improved energycane varieties with enhanced biomass yield and qualities that are suitable for cultivation in colder environments where sugarcane is not currently grown.

As in any chemical process, the quality of the raw material used for processing can affect the quality and quantity of the end product. Thus, feedstock quality of biomass destined for biorefineries will affect its value in much the same way as the quality of other agricultural products affects their use for food, animal feed, fiber and industrial products. AgCenter scientists are developing near infrared spectroscopy calibration curves to assist in the compositional analysis of energycane biomass. This provides a noninvasive tool to rapidly analyze biomass to assist the feedstock development program in selecting varieties and as a future means to assess feedstock market value.



Figure 2. Progeny from energycane crosses between sugarcane and *Miscanthus* (a) and sugarcane and *Saccharum spontaneum* (b). Note that compared with the other plants in the background, the energycane plants in the foreground in both pictures remained green after undergoing subzero temperatures.

Logistics for Sustainable Sweet Sorghum Biomass Production

H.P. "Sonny" Viator

Sweet sorghum is considered a potential crop for biofuel production in much of the tropical and temperate regions of the world. LSU AgCenter researchers are investigating sweet sorghum, along with energycane, as potential feedstock for biorefining. Sugar refinery operations, which operate for about three months beginning in October in temperate and sub-tropical regions, could be extended several months by sequentially processing sweet sorghum and energycane for biofuel production. A competitive advantage for growing sweet sorghum in the sugarcane region is that early- and medium-maturity hybrids or varieties can be planted on traditional sugarcane rows during the year that sugarcane fields are left fallow in preparation for planting. Sugarcane, a crop that regrows after harvesting, is grown on a four- to five-year cycle before it is replanted. The sweet sorghum can then be harvested and transported using sugarcane equipment in time to plant a new sugarcane crop in the fall of the year.

Expansion to more northerly latitudes beyond the confines of the traditional sugar growing region would allow for the use of full-season hybrids and varieties, which mature too late for use during the sugarcane fallow period. Unlike energycane, which does not possess sufficient cold tolerance for production above latitude 35 degrees north, sweet sorghum can be produced in a more expansive geographic zone.

LSU AgCenter researchers are studying the logistics of sustaining sweet sorghum feedstock deliveries from midsummer to the time energycane is available for processing in October, a period of three months. First generation sweet sorghum hybrids provided by Ceres Inc. were planted monthly from early April to early June in 2012 and 2013. Selected were hybrids of early, medium and late

maturity. Sweet sorghum maturity, or time from planting to flower initiation, is controlled by the length of the day (photoperiod). Some hybrids are more sensitive to the length of day than others. The 90-day hybrids, which are early-maturing, are not sensitive to day length. The 120-day, or medium-maturity, hybrids are moderately sensitive to the length of the day. The full-season hybrids won't initiate flowering until the photoperiod is a certain length of day. Temperature also plays a role and can alter the expected response to the length of day.

Individual plots were harvested as seed panicles reached the hard dough stage of maturity, approximately 30 days after mid-flowering. Fifteen stalks, with panicles and leaves intact, were randomly selected from the plots for juice and fiber analyses. Biomass weight at harvest was determined using only the center row of each three-row plot to avoid border effects. Combine extractor fans were turned off to ensure the capture of maximum biomass. Total fermentable sugar yields were estimated.

Biomass weight and total fermentable sugar yield varied considerably among hybrids and across planting dates and years. This variation was expected because of the disparities in genetic yield potential of hybrids of different maturity timelines and dissimilar growing environments associated with planting dates. Feedstock was available for processing from the initial harvest of the early-maturing, April-planted hybrids in late July until final harvest of the June-planted, late-maturity hybrids in late October, a period of three months. For both years, the lowest average fermentable sugar yields occurred for the April-planted, early-maturity hybrids and the highest average fermentable sugar yields occurred for the May-planted, medium-maturity hybrids. Biomass and sugar yields were

LSU AgCenter researchers are studying the logistics of sustaining sweet sorghum feedstock deliveries from midsummer until October.

Sweet sorghum can be grown on land that is idle between production cycles and harvested and transported using conventional sugarcane equipment.

Photo by A. Denise Attaway





According to Sonny Viator, professor and resident coordinator of the LSU AgCenter Iberia Research Station in Jeanerette, one competitive advantage for growing sweet sorghum in the sugarcane region is that early- and medium-maturity hybrids or varieties can be planted on traditional sugarcane rows during the months sugarcane fields are left fallow in preparation for planting. Additionally, sweet sorghum can be harvested and transported using sugarcane equipment before it's needed to plant a new sugarcane crop in the fall of the year. Viator is seen standing among majestic oak trees that line the road leading up to the station. Photo by A. Denise Attaway

surprising lower for the full-season hybrids than the medium-maturity hybrids. The full-season hybrids were expected to yield the highest based on their relative performance in other regions of the world. Several of these full-season hybrids, which are photoperiod sensitive, initiated flowering very late or not at all and, therefore, were harvested prior to optimal sugar accumulation.

To ensure for continual feedstock processing, refineries will have to coordinate with growers to establish production plans. For example, a refinery capable of grinding a daily quota of 1,000 tons

Scheduling required to provide 1,000 tons of sweet sorghum biomass to a mill facility on a daily basis

Planting date	Maturity group	Fresh wt. tons/acre	Acres planted	Harvest period
April	Early	18.6	753	July 15-Aug. 1
	Medium	31.5	444	Aug. 1-Aug. 15
May	Medium	42.9	326	Aug. 15-Aug. 31
	Late	38.9	360	Sept. 1-Sept. 15
June	Medium	32.1	436	Sep. 15-Sept. 30
	Late	30.0	467	Oct. 1-Oct. 15

of sweet sorghum biomass would require approximately 90,000 tons for a three-month processing season. Based upon the 2012 and 2013 information on maturity and performance for each sweet sorghum maturity group/planting date combination, it is possible to project a harvesting schedule. As shown in the table below, approximately 3,000 acres would need to be planted, with the majority of the acreage planted in April and June because of lower yields for those planting dates relative to the May planting. Additionally, because the early-maturity hybrids are relatively low yielding, a larger planting of that maturity group is required to meet the tonnage needs for the July harvest. Also, note that the scheduling for future production shown in the table did not include projections for the early planted, late-maturity hybrids or early-maturity hybrids planted after April because higher-yielding maturity/planting date combinations were available in each two-week harvest window for meeting the biomass demands. Maturity and performance of these hybrids may differ by geographic location and prevailing growing conditions. Therefore, each area will have unique circumstances.

H.P. "Sonny" Viator is a professor and resident coordinator at the Iberia Research Station in Jeanerette.

Biofuel Feedstock Acreage Potential in the Midsouth

Michael E. Salassi

Much of the focus of biofuel research involves investigating the types of crops that can be grown as feedstock material for the production of advanced cellulosic biofuels. Cellulosic biofuel refers to biofuel derived from cellulose, hemicellulose or lignin from plant, or biomass, sources. Agricultural crops with high biomass yields per acre represent ideal potential sources of feedstock material. Much of the focus of cellulosic biofuel research has been on using alternative agricultural feedstock sources that could be produced on lands not used for traditional crops. Potential feedstock crops being evaluated include crops that produce heavy yields of biomass material per acre, such as energy cane, sweet sorghum, switchgrass and miscanthus.

Just as important as determining the feedstock crops to grow in a region is determining if there is sufficient available land area within close proximity to the potential location of a feedstock processing facility. The general objective of this study was to determine the types of cropland that might be available for biofuel feedstock crop production in the Midsouth, the estimated acreage of this land, and locations where concentrations of these land types might support a great enough volume of feedstock production to be logistically feasible in a production/transportation/processing type of economic enterprise.

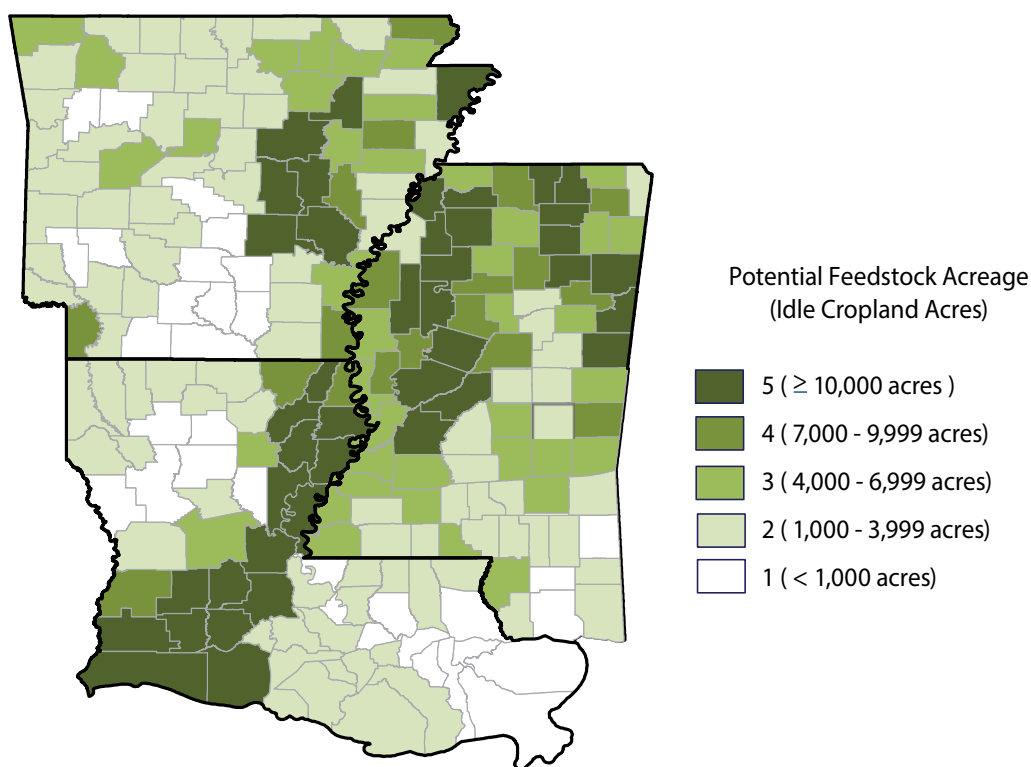
Data from the 2012 Agricultural Census were used to determine acreage levels for alternative types of agricultural land. The three Midsouth states of Arkansas, Louisiana and Mississippi were included in the investigation. County-level data for all counties in each of the three states were collected and tabulated over a range of alternative agricultural land use categories, with the specific goal of identifying land use types that might be suitable for potential

biofuel feedstock production. In addition, the data were evaluated in terms of the quantity of available acreage that could potentially be used to produce feedstock crops and the level of aggregation of these land use types across the three-state region.

Results of the evaluation showed an estimated 32.64 million acres of land in farms. This total land in farms is composed of cropland, woodland, permanent pasture and land in farmsteads. Approximately 52.9 percent of this total land area was in cropland, comprising 17.28 million acres. Total woodland and permanent pasture each comprised approximately 20 percent of total farm land area, with 6.98 and 6.61 million acres, respectively. The remaining 5 percent included land in farmsteads, which included area in farm homes, buildings, livestock facilities, ponds, roads and wasteland.

Within farm land designated as cropland, approximately 87.1 percent, or 15.05 million acres, was classified as harvested cropland, being in production each year. Ideally, the development and production of new biofuel feedstock crops would not compete with existing traditional agricultural crops on these specified acres. At least one cropland use category offers promise, and that is idle cropland. This would represent the most economically feasible cropland to bring into production with new feedstock crops, in the sense that no major land improvements or conversion practices would be needed to make the land ready for crop production.

According to the 2012 Agricultural Census, there are approximately 1.31 million acres of idle cropland in the Midsouth region. Arkansas has an estimated idle cropland volume of 312,068 acres; Louisiana has approximately 443,430 acres; and Mississippi, 558,250 acres. Given projected yield per acre estimates for potential feedstock crops, this level of cropland acreage would be more than



Distribution of Farm Land Use in the Midsouth States

Farm Land Use	Arkansas (acres)	Louisiana (acres)	Mississippi (acres)
Total cropland	7,931,111	4,275,637	5,075,579
Harvested cropland	7,316,469	3,447,617	4,292,113
Other pasture land for crops	180,875	217,145	160,511
Idle cropland	312,068	443,430	558,250
Failed cropland	88,764	37,225	37,878
Summer fallow	32,935	130,220	26,827
Total woodland	2,258,259	1,255,635	3,469,315
Woodland pastured	742,185	225,654	470,724
Woodland not pastured	1,516,074	1,029,981	2,998,591
Permanent pasture	3,123,642	1,738,667	1,751,532
Land in farmsteads	497,774	630,925	634,654
Land in farms	13,810,786	7,900,864	10,931,080

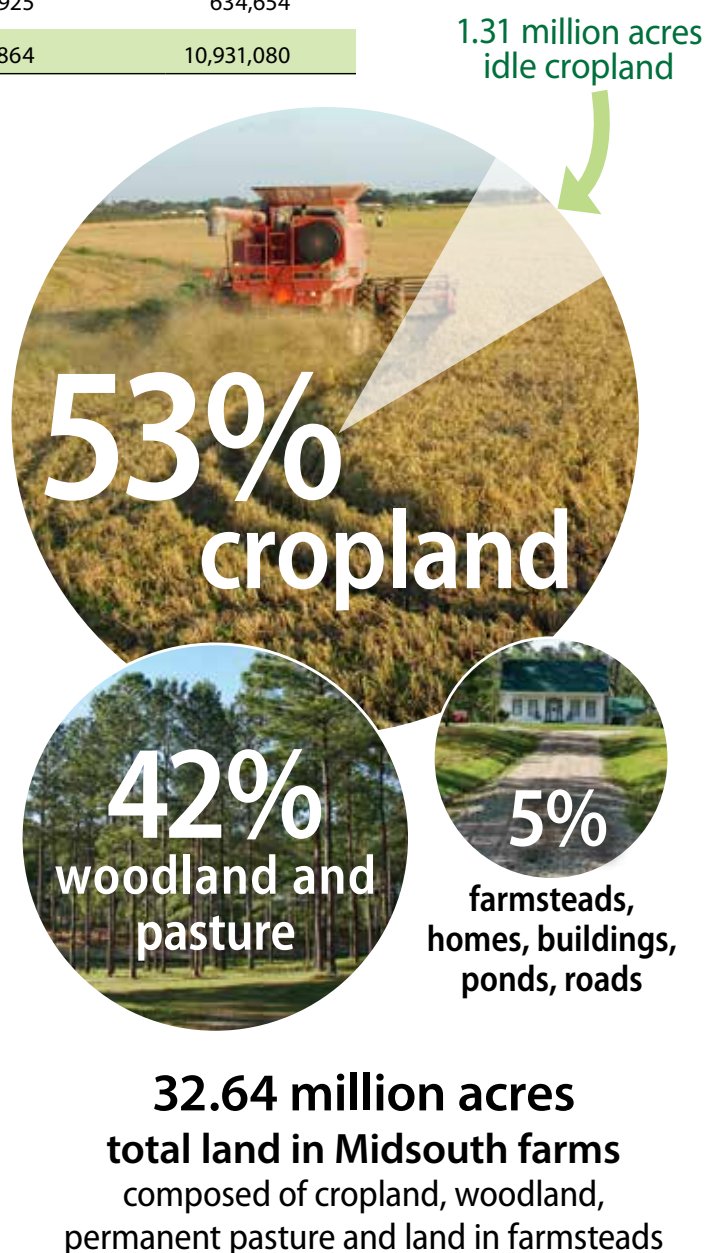
Source: 2012 Agricultural Census, National Agricultural Statistics Service, USDA.

sufficient to provide enough feedstock material to supply several biofuel processing facilities. The question is whether there are any areas within the Midsouth with a concentration of idle cropland great enough to make transportation costs from field to factory economically affordable.

Acreage levels of idle cropland were mapped at five different acreage volumes to help identify areas of idle cropland concentration. Acreage categories ranged from a low of less than 1,000 acres in the county or parish to a high of more than 10,000 acres in the county or parish. Once these acreage level categories were mapped, several locations within the three-state region were identified as having sufficient idle land to support cellulosic biofuel facilities. In Arkansas, a contingent of six counties within the east central part of the state had the highest volume of idle cropland. Louisiana had a very large contingent of parishes with idle cropland running through the traditional agricultural production areas from the southwest portion of the state up through the northeast portion of the state. In Mississippi, three to four areas appeared to have a contingent of counties with large expanses of idle cropland.

Identification of these potential biofuel feedstock crop production areas represents the first step in the potential development of a cellulosic biofuel production enterprise within the Midsouth region. However, other steps must be accomplished for an economic enterprise of this magnitude and scope to become a reality. Research on the development of potential feedstock crops that could be grown in those areas is required. Further, work must be conducted to determine the logistical possibilities of alternative biofuel processing facility locations within these areas. Finally, there needs to be an available supply of investment capital to finance the construction and operation of a cellulosic biofuel facility. Fortunately for the Midsouth region in general, and Louisiana in particular, there appears to be a sufficient volume of unused, but readily available, cropland that might serve as the production base on which such an enterprise might be developed.

Michael E. Salassi is the Nelson Fairbanks Endowed Professor in the Department of Agricultural Economics & Agribusiness.



Performance of Energycane Varieties for Power Generation and Biofuel Production

Daira Aragon, Collins Kimbeng, Shyue Lu, Donal F. Day and Benjamin Legendre

Interest in biofuel production from nonfood sources has prompted the development of high-yielding, dedicated energy crops such as energycane. Energycane varieties are high fiber sugarcane varieties that can potentially grow in more northerly climes and in marginal lands with minimal inputs. Fermentable sugars in energycane are as high as 78 percent of the sugar available in commercial sugarcane. There is an opportunity to extract these readily available fermentable sugars using roller mills or diffusers – similar to the processing of commercial sugarcane – and to use the fiber byproduct, or bagasse, as lignocellulosic biomass for release of additional fermentable sugars or for conversion into electricity. The southeastern United

States can serve as the location for new biorefineries that use energycane as the primary feedstock, taking advantage of the knowledge base created by the well-established sugarcane industry.

To adopt energycane as a commercial feedstock for the production of biofuels and bio-based chemicals, it is necessary to determine planting area, crop yields, fermentable sugar yields and product yields that would make a biomass plant operation economically feasible. Researchers at the LSU AgCenter, in partnership with other academic institutions and industries, are investigating these aspects as part of the Sustainable Bioproducts Initiative, a multi-year project funded by the U.S. Department of Agriculture. The initiative

evaluates production scenarios incorporating energycane and sweet sorghum as feedstocks into biorefinery schemes for the production of biofuels and other products such as butanol. Butanol is a fuel with a higher energy content than ethanol that does not require extensive modification to vehicle engines because of its similarities with gasoline.

Simulations of a biorefinery using an energycane feedstock were performed to project butanol yields and power generation. Simulation is a low-cost, low-risk method for determining feasibility requirements and yields of a process before physical implementation. The simulation in this study was developed using the software named SUGARS. It follows



Daira Aragon, an assistant professor at the LSU AgCenter Audubon Sugar Institute, stands next to an evaporator where juice extracted from energycane and sweet sorghum could be processed to make biofuels. Photo by A. Denise Attaway

the same principles as a sugar factory, where cane is pressed in roller mills and the juice is evaporated to obtain syrup. The bagasse remaining after pressing is either burned in boilers to generate electrical power or pretreated and hydrolyzed to obtain lignocellulosic sugars in a conversion plant that is included in the simulation model.

The simulation program was used to determine the potential for the production of butanol and the generation of electrical power from three energycane varieties – Ho 02-113, HoCP 72-114 and Ho 01-007. Table 1 shows input values used in the simulation. Crop yields for mechanically harvested material were taken from values previously reported in literature, while other data were obtained from the juice and bagasse of whole-stalk samples collected at the Sugar Research Station in St. Gabriel. The samples were analyzed at the Audubon Sugar Institute, also in St. Gabriel, for fermentable sugars (sucrose, glucose and fructose) in the juice and complex sugars (cellulose and hemicellulose) in the bagasse.

The juice extracted during milling would be used for the production of biofuels regardless of how the bagasse is used. Simulations show that up to 328 gallons per acre of butanol solvent – which is a mixture of butanol, isopropanol and ethanol – could be produced from the sugars in juice. Additional fuel can be produced from the lignocellulosic sugars released from the bagasse. In this case, potential butanol yields obtained from simulation reached 739 gallons per acre. Figure 1 shows the potential butanol solvent yields by variety using sugars from juice and lignocellulosic sugars from bagasse. Variety Ho 02-113 could produce 1,046 gallons per acre of butanol, between 19-26 percent more than the other varieties tested. Figure 2 shows the export power that can be potentially generated if the bagasse is burned in high-pressure boilers. A facility milling 10,000 tons per

Table 1. Material yield, fermentable sugar yield, fiber composition and cellulose and hemicellulose content of three energycane varieties.

Energycane Variety	Material Yield (tons/acre)	Fermentable sugar yield (tons/acre)	Fiber (% cane)	Cellulose (% fiber)	Hemicellulose (% fiber)
Ho 01-007	41.47	3.34	20.65	40.50	24.13
Ho 02-113	44.44	3.17	26.23	39.87	24.04
HoCP 72-114	34.37	2.27	27.72	39.86	25.15

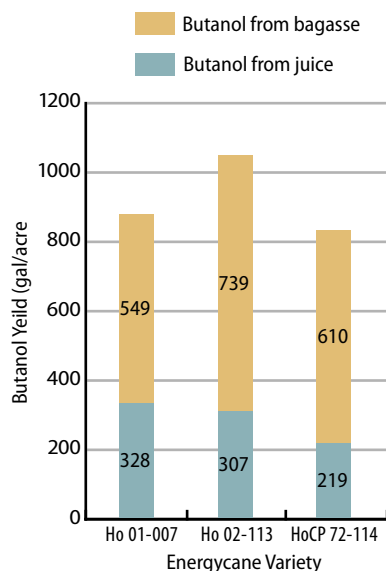


Figure 1. Potential butanol solvent yields by variety using sugars from juice and lignocellulosic sugars from bagasse (gallons per acre).

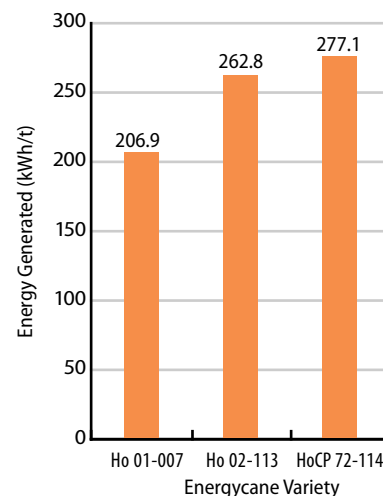


Figure 2. Potential export power that can be generated if the bagasse is burned in high-pressure boilers (kilowatts per ton).

day of variety HoCP 72-114 during 120 days has the potential to generate enough power to supply more than 22,000 homes in Louisiana for an entire year (average household consumption of 1,253 kilowatt hours per month).

Variety Ho 02-113 gives the best total butanol production. In terms of power generation, HoCP 72-114 presents the best performance for power generation per ton of cane. However, processing the same acreage of each variety will place Ho 02-113 at the top of the list because of its higher crop yield, producing 22 percent more electricity than HoCP 72-114 and 36 percent more than Ho 01-007. Overall, variety Ho 02-113, with production of more than

1,000 gallons per acre of butanol and 110 megawatts of power for export, has the greatest potential to become a feedstock in commercial production of biofuels and power. Energycane yields may vary by location and year. Nonetheless, these production figures are a good indication of what could potentially be obtained. Because energycane would have a longer harvesting season than sugarcane, October through March, sugar factories in Louisiana could complement their season by processing variety Ho 02-113 and exporting electricity to the grid or producing fermentable sugar syrup and bagasse to supply a biorefinery.

Daira Aragon is an assistant professor at the Audubon Sugar Institute, St. Gabriel. Her co-authors are Collins Kimbeng, an associate professor, Sugar Research Station, St. Gabriel; and Shyue Lu, research associate, Donal F. Day, professor, and Benjamin Legendre, professor and department head, Audubon Sugar Institute.

Potential Ethanol, Butanol Production from Sweet Sorghum, Energycane

Daira Aragon, Shyue Lu, Sonny Viator, Collins Kimbeng and Franz Ehrenhauser

The need for decreasing greenhouse gas emissions, exhaustion of fossil fuel resources and the desire for energy independence have encouraged worldwide interest in fuels and chemicals derived from renewable resources, especially those that do not compete with food crops. The economics of the renewable fuel market requires regional production of feedstocks and use of available infrastructure. In the case of Louisiana, the well-established sugarcane industry provides the perfect logistics and infrastructure to produce and process cane-type material. Energycane and sweet sorghum are top candidates because of their physical and compositional similarities with sugarcane. Researchers have reported that sweet sorghum can be harvested in Louisiana during the months of August and September, with possibilities of harvesting as early as July. Energycane can be harvested from October through March. These harvesting seasons would complement commercial sugarcane operations, potentially extending the grinding season of October through January for an additional four to six months. Fuels can be produced from the sugar in the juice and the sugars in the bagasse through fermentation. The juice does not need extensive conditioning before fermentation. The bagasse must be pretreated and hydrolyzed to release simpler sugars (lignocellulosic sugars) that can be used by the yeast or bacteria.

Determining product yields that can be obtained from sweet sorghum and energycane is one of the first steps in evaluating the economics of adopting these crops in Louisiana. This requires simulation to predict fuel production based on measured values such as sugar content (sucrose, glucose, fructose, xylose), fiber content and bagasse composition (cellulose, hemicellulose). Simulation of a facility producing fermentable sugar syrups was performed using the software SUGARS to determine the potential production of ethanol and butanol from sweet sorghum and energycane. The first simulation was as a sugar factory, where the juice is extracted from the crops and evaporated into syrup. The second section was a lignocellulosic conversion plant, where the fiber (bagasse) remaining after

juice extraction is pretreated and hydrolyzed to release glucose and xylose. Finally, the simulation model included high-pressure boilers to produce power for export by burning bagasse when it is not used for sugars. To evaluate the full potential of these crops, all the bagasse was used for fuel production or power generation for export. Data for whole-stalk samples of sweet sorghum and energycane used in the simulation are in Table 1.

Fermentable sugars from juice and fiber were used to calculate ethanol and butanol production using current attainable conversions reported in literature. Figure 1 shows annual fuel production for sweet sorghum and energycane harvested for 60 days and 120 days, respectively, at a grinding rate of 10,000 tons per day. A biorefinery based on sweet sorghum and energycane potentially could produce more than 57 million gallons of ethanol or more than 41 million gallons of butanol per year using existing technologies. Nearly 52,000 acres would be necessary to reach these production capacities using juice and bagasse. If all the bagasse is burned in high-pressure boilers, the potential power generated would be enough to power about 30,000 homes in Louisiana.

Certain considerations need to be addressed because of the seasonal character of the energycane and the sweet sorghum crops to ensure that supply will not be halted. This constant supply can be accomplished by storing bagasse or juice as concentrated syrup during the three to five months off-season. Simulation shows that in order to have a constant fuel supply during the year, it would be necessary to store up to 483,000 tons of bagasse or 55 million gallons of syrup per processing plant. Syrup storage has advantages over storing bagasse because of easier handling, reduced fire hazard and reduced processing cost.

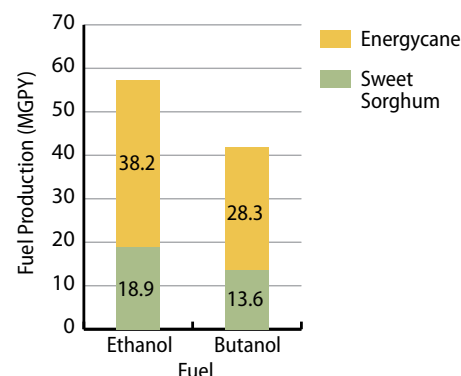


Figure 1. Annual fuel production for sweet sorghum and energycane harvested for 60 days and 120 days, respectively, at a grinding rate of 10,000 tons per day (million gallons per year).

Louisiana's sugar industry has the potential of becoming a front-end plant for future biorefineries or biopower producers, taking advantage of the knowledge and infrastructure already in place. Up to 100,000 acres could be available to plant sweet sorghum and energycane during the sugarcane fallow period. To process this acreage at a rate of 10,000 tons per day during 180 days, only two of Louisiana's 11 sugar factories would be necessary. The potential annual production in the state could reach 228 million gallons of ethanol or 164 million gallons of butanol. Energycane and sweet sorghum are considered low-input crops that could be grown in colder climates than sugarcane. Research shows the crops can be grown as far north as Winnsboro and on land not suitable for food-producing crops such as corn and soybeans.

Ultimately, the adoption of energycane and sweet sorghum will be subjected to the successful development of crop production systems and processing technologies that guarantee competitiveness with petroleum-based fuels. Current government incentives are helping researchers and companies move forward.

Table 1. Composition of whole-stalk sweet sorghum and energycane used in simulation.

Feedstock	Fermentable sugars (% juice)	Juice (% cane)	Fiber (% cane)	Cellulose (% fiber)	Hemicellulose (% fiber)
Energycane	9.67	73.77	26.23	39.87	24.04
Sweet Sorghum	12.02	79.01	20.99	40.47	23.35

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Butanol Fermentation of Louisiana Biofuel Crops

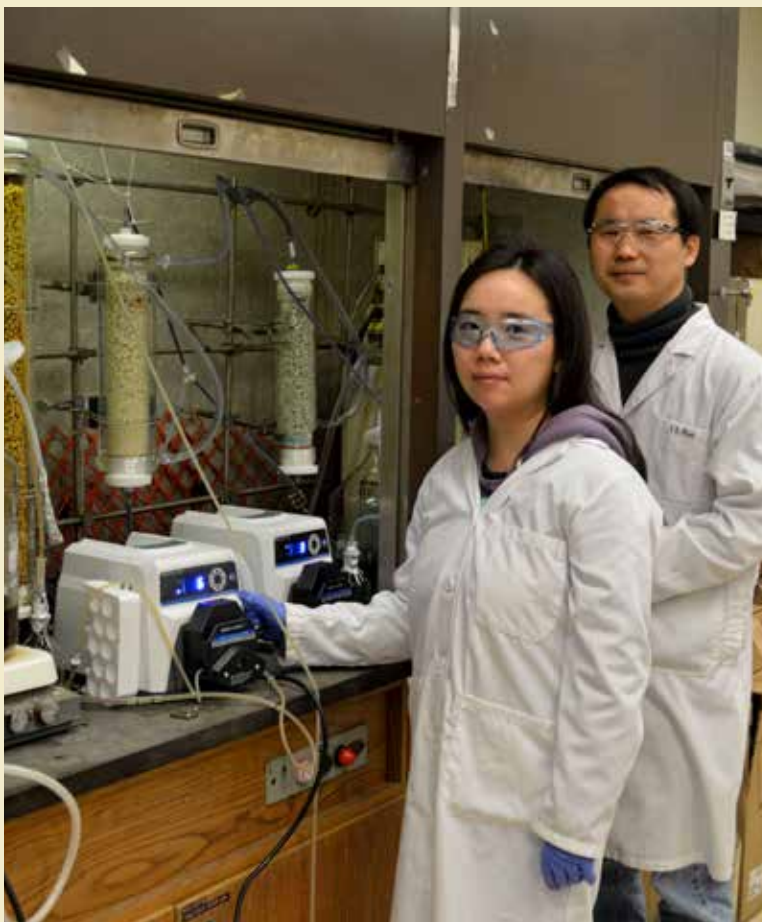
Young Hwan Moon and Ying Yang

Butanol as a biofuel has many advantages over ethanol as a fuel, including higher energy content, usability in existing pipelines and ease of blending with gasoline. Butanol can be produced from the sugars in biomass. Unlike ethanol, butanol does not absorb water, allowing it to be stored and distributed using the existing petrochemical infrastructure and avoiding the blending limitations of ethanol. Butanol is compatible with gasoline and diesel at any ratio and can be used directly as a fuel in existing vehicles. Butanol has been tested as a jet fuel at a 50-50 blend with current jet fuel. Because of its higher energy content, its fuel economy in miles per gallon is better than that of ethanol. Butanol-gasoline blends have lower vapor pressure than ethanol-gasoline blends, which is important in reducing evaporative hydrocarbon emissions. This is valuable to fuel refiners and blenders because a lower vapor pressure allows the light fractions derived from oil refining to be used in the higher-value gasoline.

A number of *Clostridium* strains, including *Clostridium acetobutylicum*, *Clostridium butylicum* and *Clostridium beijerinckii*, are butanol-producing organisms. Acetone-butanol-ethanol (ABE) fermentation using these strains is one of the oldest known industrial fermentations. It is ranked second only to ethanol fermentation by yeast in its scale of production. This process produces large quantities of hydrogen, ethanol, acetone, acetic acid and butyric acid, limiting the yield of butanol to around 0.35 grams of butanol per gram of glucose consumed.

In typical ABE fermentations, *Clostridium* strains produce acetone, butanol and ethanol in a ratio of 3:6:1, with the concentration of total solvents of up to 2.4 percent. Numerous attempts have been made to manipulate the genetics of the organism to produce higher yields of butanol and to reduce acetone production to simplify downstream processing. However, attempts to block acetone production to increase selectivity for butanol production result in loss of butanol because acetone and butanol share a common intermediate.

Clostridium beijerinckii optinoii is a butanol-producing bacterium that was isolated by a microbiology team at the Audubon Sugar Institute. *Clostridium beijerinckii optinoii* produces butanol, isopropanol and very little ethanol or acetone in a ratio of 6.0:3.8:0.2, unlike other ABE organisms where the ratio is 6:3:1. Acetone is not considered to be favorable for downstream processing because of its corrosiveness and volatility. The butanol-isopropanol mix produced by *Clostridium beijerinckii optinoii* is expected to be more practical for butanol production than the butanol-acetone mix from the ABE fermentations. Because of low productivity for butanol in batch fermentation, a system has been developed to improve butanol productivity. The productivity of butanol only in



Young Hwan Moon and Ying Yang check continuous fermentation reactors of *Clostridium* strains used to make butanol at the LSU AgCenter Audubon Sugar Institute. Photo by A. Denise Attaway

batch fermentations with *Clostridium beijerinckii optinoii* is around 0.12 grams per liter-hour, whereas the productivity of butanol under continuous immobilized fermentation is up to 0.65 grams per liter-hour in a glucose medium – a five-fold increase in productivity.

Under an LSU AgCenter program funded by the U.S. Department of Agriculture, sweet sorghum and energy-cane are being studied as biofuel feedstocks. Using these crops, researchers are producing butanol from the crops' component sugars through microbial fermentation with the *Clostridium* bacterium. Sugarcane molasses normally is used as the feedstock for butanol fermentations. Sugarcane molasses contains sucrose, fructose and glucose. The test crops will produce syrups containing the same sugars. The biomass can be converted to glucose and xylose, a sugar also used by this organism. These biomass crops may offer a new way for producing butanol as a biofuel.

Young Hwan Moon is an assistant professor, and Ying Yang is a postdoctoral researcher at the Audubon Sugar Institute in St. Gabriel.

Conversion of Cottonwood and Switchgrass to Charcoal via Carbonization Process

Sammy Sadaka, Hal Liechty, Matthew Pelkki and Michael Blazier

Crop biomass can be co-fired with coal to produce energy. Co-firing has the potential to reduce carbon dioxide emissions from coal-fueled plants. Research has demonstrated that when co-firing is conducted with relatively low ratios of biomass to coal, there are significant reductions in both solid waste generation and emissions. However, the nature and chemical composition of raw biomass can lead to significant increases in infrastructure costs or reactor problems if co-firing is conducted with high ratios of biomass to coal. Moreover, high biomass-to-coal ratios may increase reactor corrosion and decrease efficiency. Consequently, co-firing using high proportions of raw biomass is a challenging process for heat and power production systems.

Ameliorating raw biomass physiochemical properties and concentrating its energy density could increase acceptance of biomass for co-firing operations. Carbonization is a promising thermochemical process that can produce biomass with properties comparable to coal and make biomass feedstocks more favorable for co-firing. Carbonization, which takes place in the absence of oxygen at temperatures of 750-930 degrees F, converts raw biomass into charcoal-like feedstock. During the carbonization process, biomass chemical bonds break down, producing a charcoal-like material in addition to combustible gases and tar. Carbonization breaks down the complex substances in biomass into elemental carbon and chemical components.

Cottonwood and switchgrass from LSU AgCenter and University of Arkansas research sites were used for a carbonization experiment. Woody biomass is more suitable than many other energy sources for co-firing because it contains fewer ash and alkali components. Switchgrass can also be co-fired with coal as a cleaner-burning energy alternative to low-grade coal. Biomass samples were carbonized in a carbonization reactor and placed in a muffle furnace at 750 degrees F for two hours. The weight loss of the sample was determined after allowing the

sample to cool down. Physical, chemical and thermochemical characteristics of raw and carbonized biomass were measured.

Feedstock volatile matter values were determined by heating the feedstock under controlled conditions and measuring weight loss, excluding the weight of moisture. The initial volatile matter content was 78.0 percent for cottonwood and 73.9 percent for switchgrass. Generally, carbonization significantly reduced the volatile solids content of cottonwood to 25.3 percent and of switchgrass to 25.9 percent. Ash content and fixed-carbon content increased significantly for the cottonwood and switchgrass samples. The ash content values increased from 1.8 percent to 5.8 percent for cottonwood and from 4.9 percent to 10.6 percent for switchgrass. Fixed carbon also showed similar trends, with a change in cottonwood from 20.2 percent to 68.6 percent. Switchgrass fixed carbon also increased from 21.2 percent to 63.4 percent. Carbonization drives off hemicellulose and cellulose from the biomass, leading to an overall reduction of the sample weight. This reduction led to the increases in ash and fixed-carbon contents.

Carbonization is a promising thermochemical process that can produce biomass with properties comparable to coal and make biomass feedstocks more favorable for co-firing.

Analyses were also performed on the raw and carbonized cottonwood and switchgrass samples to determine their carbon, hydrogen, oxygen and nitrogen contents. Carbon, hydrogen, oxygen and nitrogen for raw cottonwood and switchgrass were not significantly different from each other. The carbonization process increased carbon and nitrogen concentrations, but it decreased hydrogen and oxygen concentrations. Carbon concen-



Five-year-old cottonwood trees immediately before harvest as biofuel feedstock and switchgrass bales harvested for biofuel production at a study site in Archibald, Louisiana. Photo by Michael Blazier

tration increased from 49.7 percent to 74.9 percent for cottonwood and from 47.8 percent to 56.0 percent for switchgrass. The increase in carbon concentration and the decrease in oxygen concentration decreased the oxygen-to-carbon ratio for the carbonized biomass compared with the raw biomass. The oxygen-to-carbon ratio decreased from 0.65 to 0.21 for cottonwood and from 0.62 to 0.47 for switchgrass. During carbonization of feedstock, hemicellulose decomposes significantly, followed by cellulose. This was observed during the carbonization process, resulting in the decline of the oxygen-to-carbon ratio in feedstock. The reduction of the oxygen-to-carbon ratio in the carbonized fuel would enhance its combustion behavior. The values of the oxygen-to-carbon ratio of the carbonized feedstock are approaching that of lignite coal (0.35-0.45).

The average heating values were 7,738 Btu per pound for raw cottonwood and 6,964 Btu per pound for raw switchgrass. Carbonization of cottonwood and switchgrass positively affected the heating values. The heating values increased to 12,381 Btu per pound for carbonized cottonwood and increased to 11,779 Btu per pound for carbonized switchgrass. These increases in energy concentrations may be attributed to the release of the non-combustible vapors and gases from the biomass during the carbonization process. In other words, the heating value of the feedstock increased due to the increased concentration of the combustible components in the produced charcoal. The mechanisms of carbonization process described earlier would provide an explanation of the higher-density energy of carbonized material.



Harvesting cottonwood at a research site in Archibald, Louisiana. Photo by Michael Blazier

Conclusions

Carbonization was effective at converting cottonwood and switchgrass into charcoal that had some properties similar to coal. As such, carbonized biomass from these feedstocks could be viably co-fired with coal to enhance use of renewable materials in large-scale heat and power production systems. Heating values were 1.7 times greater for carbonized biomass relative to raw biomass for both feedstocks. Heating values for cottonwood and switchgrass were similar, but cottonwood had ash contents nearly half those of switchgrass.

Acknowledgements

This research was funded by Sun Grant and USDA Sustainable Agriculture and Research Education programs until 2013 and currently is supported by the Agriculture and Food Research Initiative of the National Institute of Food and Agriculture.

Sammy Sadaka is an assistant professor and extension engineer in the Department of Biological & Agricultural Engineering, University of Arkansas Division of Agriculture. Hal O. Liechty is George R. Brown Endowed Professor, and Matthew H. Pelkki is a professor and Clippert Chair in the School of Forest Resources, University of Arkansas at Monticello. Michael Blazier is an associate professor at the LSU AgCenter Hill Farm Research Station, Homer.



Collecting switchgrass samples at a research site in Rohwer, Arkansas. Photo by Hal Liechty

Near Infrared Spectroscopy

A Rapid Analytical Technique for Quantification in Biofuel and Biochemical Production

Shyue Lu

Biofuel production is an extensive process that involves developing a biological feedstock, processing and treating the feedstock, and producing and refining fuels and chemicals from the feedstock. In every step of the process, analytical quantifications are needed to maintain efficacy. Research has shown near infrared spectroscopy to be an ubiquitous analytical technique that could fulfill this need. This tool can be calibrated to identify and quantify most, if not all, of the components of interest of both solid and liquid samples from feedstock to final product with usable results obtainable within a matter of minutes. The versatile and adaptive nature of this analysis makes it well suited for the critical needs of biofuel and biochemical production at every stage.

Spectroscopy is a common analytical technique that has been studied since the 17th century. It involves the use of light from any part of the electromagnetic spectrum to reveal information about a sample. Near infrared spectroscopy specifically uses light just past red of the visible spectrum. When infrared light hits sample matter, it causes vibrations in the bonds between atoms. These vibrations can be detected as peaks, including a first fundamental peak and several resonating peaks that follow. The fundamental peaks occur in the mid infrared range and can be directly associated with a chemical component. Near infrared spectroscopy, however, focuses on the smaller resonating peaks and the combinations of peaks that occur from overlapping resonating peaks of different chemical components. This technique is unique in spectroscopy in that you cannot directly associate a peak to a specific chemical component because there is just too much information in the spectra from the scan.

Until the 1990s, near infrared spectroscopy was obscure and rarely used because it was nearly impossible to get usable data out of its spectra. However, with the development of mathematical algorithms called chemometrics, the information-saturated spectra became not only usable, but an asset. With increasingly advanced computing power, chemometric software can use laboratory



Shyue Lu is pictured with the Spectracane near infrared spectroscopy system at the Sugar Research Station in St. Gabriel. Whole stalks of energycane and sweet sorghum are fed directly into the Spectracane for analysis. Photo by Denise Attaway

data from primary analysis methods to decode near infrared spectra of a sample and create calibration models. These calibration models can then be used to quickly analyze unknown samples.

Since the development of chemometric software, near infrared spectroscopy applications have been rapidly expanding into a variety of fields including chemistry, textiles, pharmaceuticals, industrial process control and agriculture. Examples of use in these fields include identifying chemicals such as water, alcohols, and proteins; differentiating polymeric fibers in textiles; quality control in pharmaceutical drugs; and ensuring industrial processes are on track.

The agricultural industry makes extensive use of near infrared spectroscopy technology. For example, fruits and vegetables are scanned intact without any destructive sample preparation to determine properties such as sugar content, dry matter percentage and acidity. Sugarcane is an agricultural crop commonly characterized with near infrared

spectroscopy for qualities important in sugar crystallization and used to calculate theoretical recoverable sugar.

Many potential biofuel feedstocks are agricultural products or byproducts. At the LSU AgCenter, biofuel research is focused on sweet sorghum and energycane. These particular feedstock sources provide energy in two forms: readily available fermentable sugars in expressed juice and complex sugars tied up in the fibrous material referred to as lignocellulosic sugars that require further processing. Near infrared spectroscopy is the technique chosen to characterize raw feedstock and determine how much sugar is potentially available for fermentation.

Analytical laboratory techniques are already available to provide primary analysis data to develop near infrared calibration models for components in the juice, including sugars and ash, and components in the fiber, including cellulose, lignin and ash. The process for obtaining this data is time consuming and requires advanced training; thus, it is not a viable

solution for analyzing a large number of samples. With the addition of near infrared spectroscopy, it is possible to analyze a smaller number of samples with traditional methods, build near infrared spectroscopy calibration models with that data, and analyze the majority of samples using only a near infrared spectroscopy scan.

The process for obtaining a scan of sweet sorghum or energycane begins with feeding 10 pounds of whole, hand-harvested material into a hammer mill shredder. This material travels via conveyor belt into a homogenizer, which mixes the sample material and packs it into a “cake” to remove any gaps. This sample “cake” travels past the transmission head, which records multiple scans of the material and creates an average spectra representative

of the sample’s response to near infrared light. This process happens within one to two minutes per sample and results can be immediately obtained from the chemometric software. Being able to obtain characteristic data this quickly on a large number of samples allows agronomists to more effectively make decisions in breeding and developing feedstock best suited for the needs of biofuel production. This rapid analysis can also be used to determine payment scales for feedstock growers based on the quality of the crops being sold.

While feedstock may be the primary application focus of near infrared spectroscopy in the early stages of biofuel production, it has applications throughout the process. Benchtop versions of near infrared spectroscopy instrumentation

allow for the scanning of small liquid and solid samples. Any intermediate samples from the process can be monitored for consistency. For example, fermentation products can be analyzed for the amount of butanol available for purification. Final products can also be analyzed for purity and identification of common contaminants. Coupling the analytical abilities of near infrared spectroscopy with powerful advances in chemometric computing allows for useful applications throughout the biofuel and biochemical production process.

Shyue Lu is a research associate at the Audubon Sugar Institute in St. Gabriel.

SCIENCE NOTE

Dilute Ammonia Pretreated Sorghum and Energycane Bagasse Enzyme Hydrolysate Liquor for Syrup Production

Patrisha J. Pham-Bugayong and Giovanna M. Aita

Lignocellulosic biomass – which includes agricultural residues such as corn stover and sugarcane bagasse, herbaceous crops such as switchgrass, and both hard and soft woods – is an important source of fermentable sugars and other valuable components. These fermentable sugars can be converted to ethanol, butanol and other value-added chemicals. However, pretreatment is necessary before access to these sugars is possible. There are numerous, well-studied processes in which to treat the biomass without sacrificing fermentable sugar yields. These include treating with acids, water usually in the form of steam and ammonia or other basic ingredients.

For this study LSU AgCenter researchers used bagasse from sweet sorghum and high-fiber sugarcane, also known as energycane, and pretreated with dilute ammonia. After the pretreatment process, the biomass was mixed and converted to specific fermentable sugars. A cocktail of commercially available enzymes was used in various combinations. The results show a mix of monomeric and oligomeric sugars in the sorghum and energycane enzymatic hydrolysate liquor.

The pretreatment and enzymatic hydrolysis processes that soften and break down the biomass generate fermentable sugars but also undesirable

nonsugar components, which require removal through detoxification. For this study, the enzyme hydrolysate liquor derived from sorghum and energycane pretreated biomass was characterized for sugar and nonsugar components to aid in the design of an effective detoxification strategy. The researchers explored detoxification strategies successful in obtaining maximum sugar recoveries while nonsugar components were kept at low levels. The successful detoxification strategies include ionic liquids and ion-exchange resins, as evidenced by the removal of most inhibitors. Ionic liquids are salts that are liquid at room temperature and possess several unique properties when compared to regular organic solvents. These properties are useful for separation applications. Ion-exchange resins, on the other hand, are made up of an insoluble matrix of an organic polymer substrate, which is widely used for separation and purification processes as well.

The detoxification strategies chosen were optimized and applied to the



Patrisha Pham-Bugayong, left, and Giovanna Aita are studying ways to make syrup from energycane and sweet sorghum bagasse to be used as feedstock for the generation of biofuels and chemicals in Aita’s lab at the LSU AgCenter Audubon Sugar Institute. Photo by A. Denise Attaway

enzyme hydrolysates. Results showed that the strategies had no significant effect on monomeric sugar levels while the nonsugar components were minimized. The fermentable monomeric sugars obtained after detoxification can be converted into syrups, which can be stored for future use. This mixed sugar syrup feedstock can be converted to biofuels or introduced into processes to make chemicals. The nonsugar components can be recovered and converted into useful chemicals as well. These detoxification strategies can also be applied to other enzymatic hydrolysate liquors derived from other biomass available in Louisiana.

Patrisha J. Pham-Bugayong is a post-doctoral fellow, and Giovanna M. Aita is an associate professor at the Audubon Sugar Institute, St. Gabriel.

Insect Pests and Diseases in Bioenergy Crops

Gene Reagan, Ted Wilson, Julien Beuzelin, Mo Way, Jeff Hoy, Yubin Yang, Allan Showler, Matt VanWeelden and Blake Wilson



Figure 1. Blake Wilson, LSU AgCenter research entomologist, poses with sweet sorghum on the left and high biomass sorghum on the right at a research field site in St. Mary Parish. Photo by Matt VanWeelden

With plentiful rainfall, abundant land and mild winters, south Louisiana is among the geographic regions with the highest potential for production of dedicated cellulosic bioenergy crops, especially energycane and high-biomass sorghum (Figure 1). Additionally, much of the infrastructure needed for production of bioenergy crops is already in place because the sugarcane industry has been thriving in our state for centuries. However, insect pests and diseases have historically been major yield-limiting factors in the South. LSU AgCenter and Texas A&M AgriLife scientists are working together with the goal of building a landscape-wide pest management program that will mitigate insect pest and disease damage

to bioenergy crops in interaction with conventional crops along the U.S. Gulf Coast.

An old foe, the sugarcane borer

The sugarcane borer, *Diatraea saccharalis*, has been the primary pest of sugarcane in Louisiana for more than a century. The insect also feeds on other crops, including corn and rice, and is expected to be a pest of bioenergy crops including energycane, sweet sorghum and high-biomass sorghum. Sugarcane borer larvae tunnel internally in stalks, reducing the flow of nutrients within the plant. Sugarcane borer injury is most commonly assessed by determining the proportion of bored internodes, which is directly related to reductions in yield.

While the pest is controlled in sugarcane with judiciously timed insecticide applications and conservation of natural enemies, management in bioenergy cropping systems presents a new challenge. Insecticide recommendations are developed from insect injury to yield loss relationships, which are different for bioenergy crops than for conventional sugarcane. Studies conducted in the sugarcane production region of St. Mary Parish, where high pest populations occur, indicate sorghum varieties may be more susceptible to sugarcane borer damage than energycane or conventional sugarcane (Table 1). Thus, in areas where sugarcane borer problems are common in sugarcane, sugarcane borer problems are also expected in bioenergy crops. If infestations in bioenergy crops are not controlled, they could increase pest pressure on surrounding fields of conventional crops.

An emerging threat, the Mexican rice borer

The Mexican rice borer, *Eoreuma loftini*, is the primary pest of sugarcane in Texas and has been making its way eastward since the 1980s (Figure 2). It first arrived in Louisiana in 2008 and is now in eight southwestern parishes (Figure 3). The Mexican rice borer thrives in crops already stressed by factors such as drought. Chemical control of this pest is made difficult because the larvae quickly bore into stalks, escaping exposure to insecticides and natural enemies. Many sugarcane farmers in Texas have abandoned the use of insecticides to control this pest.

Studies at the Texas A&M AgriLife Research Center at Beaumont evaluated Mexican rice borer injury and associated yield reductions in conventional and bioenergy sugarcane and sorghum varieties. Results indicate this pest has potential to have a serious impact on the production of biofuels along the Gulf Coast. The thinner stalks and higher fiber content of energy-

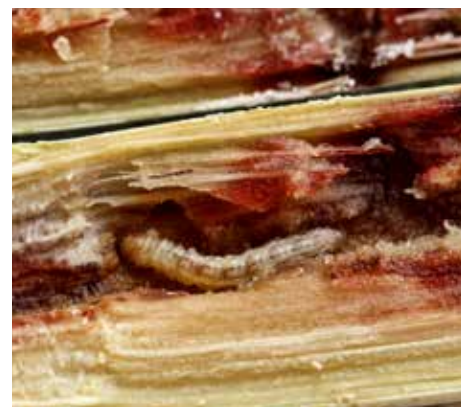


Figure 2. Mexican rice borer larval tunneling in a sugarcane stalk. Photo by Anna Mészáros

cane relative to conventional sugarcane and sorghum may reduce susceptibility to Mexican rice borer injury. However, yield losses of 1 to 3 percent per 1 percent bored internodes were observed in all bioenergy varieties evaluated.

Aphids and other pests attack bioenergy crops

The sugarcane aphid, *Melanaphis sacchari*, has been garnering a lot of attention in recent years. Severe outbreaks have devastated grain sorghum fields from Texas to South Carolina. These tiny insects suck vital nutrients from plants and secrete sticky honeydew, which promotes growth of black sooty mold (Figure 4). Section 18 Emergency Exemption use labels granted by the EPA have allowed a newer, more effective insecticide to be sprayed on grain and forage sorghum to help control recent outbreaks. However, currently labeled pyrethroid insecticides for sugarcane and bioenergy crops often provide poor aphid control and can even flare infestations because of suppression of beneficial insects. Infestations of aphids in research plots of high-biomass and sweet sorghums in Beaumont, Texas, reached damaging levels in 2013 and 2014, despite multiple insecticide applications. In addition, the sugarcane aphid is a vector of several plant viruses, including sugarcane yellow leaf virus. Surveys found this virus in one out of 10 sugarcane fields, with an incidence of 2 percent in 2011 and two out of 10 fields with incidences of 4 percent and 18 percent in 2012. Results suggest mixed cropping

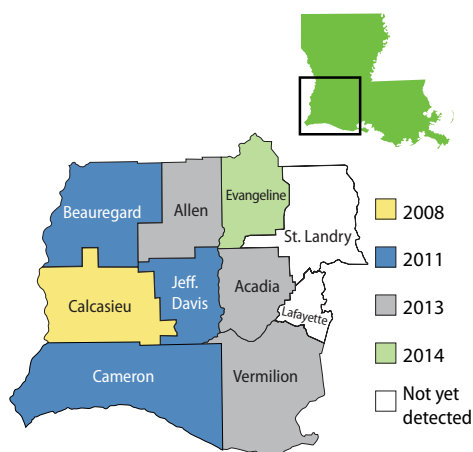


Figure 3. Mexican rice borer range expansion into Louisiana.

Table 1: Sugarcane borer injury and associated yield loss to bioenergy and conventional crops in St. Mary Parish.

		2012		2013	
		% Bored Internodes	% Yield Loss*	% Bored Internodes	% Yield Loss*
High-Biomass Sorghum	ES 5140	10.1	22.4	4.4	6.9
	ES 5200	16.2	24.3	7.6	13.7
Sweet Sorghum	M81E	14.6	26.1	6.4	17.6
Energycane	L 79-1002	11.1	10.5	6.1	14.9
	Ho 02-113	5.1	5.8	1.8	7.1
Sugarcane	HoCP 00-950 (Susceptible)	17.7	18.8	10.0	11.1
	HoCP 85-845 (Resistant)	3.4	9.0	1.9	7.7

*Yield loss based on stalk fresh biomass.

systems with sugarcane, sorghum and corn could affect virus incidence; however, the study size was not sufficient to draw definitive conclusions.

In research plots of bioenergy crops in Rapides Parish, high-biomass sorghum varieties were heavily damaged by grass mites, *Oligonychus pratensis*, and stalk rot, *Fusarium* spp. (Figure 5). These observations further add to the diversity of insect and disease pests expected in production of bioenergy crops in Louisiana.

Because of overlap in insect and disease pests of sugarcane, grain sorghum and crops produced for biofuels, expanded production of bioenergy crops is anticipated to have wide-ranging effects on Louisiana agriculture. Ongoing cooperative research efforts focus on development of a Web-based regional management program based on landscape-wide simulations of stem borer populations that allow for rapid analysis and selection of optimal field- and regional-level management approaches.



Figure 4. Sooty mold growing on honeydew produced by sugarcane aphids on sweet sorghum. Photo by Blake Wilson



Figures 5a and 5b. Injury to high-biomass sorghum by stalk rot (top) and grass mites (bottom). Photos by Matt VanWeelden

Gene Reagan, Austin C. Thompson Professor of Sugarcane Entomology, Department of Entomology; L.T. (Ted) Wilson, Jack B. Wendt Endowed Chair in Rice Research, Center Director, Texas A&M AgriLife Research Center at Beaumont; Julien Beuzelin, Assistant Professor of Entomology, Dean Lee Research and Extension Center, Alexandria; M.O. Way, Professor of Entomology, Texas A&M AgriLife Research Center at Beaumont; Jeff Hoy, Professor of Sugarcane Pathology, Department of Plant Pathology and Crop Physiology; Y. Yang, Senior Biological Systems Analyst, Texas A&M AgriLife Research Center at Beaumont; Allan Showler, Research Entomologist, USDA-ARS, Kerrville, Texas; Matt VanWeelden and Blake Wilson, Department of Entomology.

Producing Energy Pellets from Dried Animal Waste and Biomass

Chandra Theegala

Forestry and poultry, the top two income-producing agricultural commodities in Louisiana generate significant quantities of waste that can be used for producing energy pellets or other value-added products such as soil amendments.

The forestry industry produces enormous quantities of sawdust that is not suitable for energy production because of its low bulk density and high moisture content. If end users are not identified within reasonable hauling distances, the full economic potential of the sawdust is not realized.

The magnitude of waste from the poultry industry is the primary reason for concern. Because of the costs associated with hauling the material over long distances, poultry litter is often overapplied to nearby land, leading to excess nutrients and pathogens in runoff water.

Apart from these two primary wastes, significant quantities of crop residues are underutilized. Louisiana also has the potential to generate enormous quantities of dedicated energy crops such as switchgrass, energycane and kenaf.

Therefore, generating energy from this waste and biomass is both economically logical and environmentally sustainable. Because most of these wastes have relatively high moisture and low bulk density, it is important to dry the waste and make it into pellets. If the waste is generated from animal operations, pathogen elimination or pellet sterilization may be warranted.

Energy content quantification experiments in the Department of Biological and Agricultural Engineering indicate the energy content is 6,879 Btu per pound of pine sawdust, 5,116 Btu per pound of separated dairy manure and 5,030 Btu per pound of poultry litter. Results also indicate that pine has the highest percentage of volatile solids (99.9 percent) and least amounts of ash. However, both animal waste samples had volatile solids contents around 83 percent, thereby indicating that pure animal waste pellets may not be ideal for burning and may require some degree of blending with biomass with low ash content. However, animal waste pellets are ideal as soil amendments because of their high nutrient content.



Figure 2. Pellets

Freshly collected poultry litter and biomass have a moisture content of up to 50 percent or higher. Therefore, for low-value applications like producing bioenergy, using electrical energy or fossil fuel for removing moisture is prohibitively expensive and impractical. Oftentimes, the energy required for drying the material far exceeds the energy it contains. On the other hand, solar energy, which is abundant and free, can be used for drying these materials. LSU AgCenter research on custom-designed solar stills (Figure 1) has demonstrated that biomass with moisture content as high as 70-80 percent can be dried to less than 4 percent moisture in less than three to four summer days.

Research has demonstrated that the extremely high temperatures (above 200 degrees F) in the solar still may not be enough for bacterial sterilization or pathogen elimination for soil amendment or fertilizer applications. However, high moisture content in the still together with solar heat effectively lowered the fecal coliform, *E. coli* and total coliform counts.

Solar still-dried biomass can be pulverized, if necessary, and fed into a pellet mill, which extrudes the pellets from a rotating die on which frictional rollers are attached (Figure 2). Results indicate that biomass with a 10-15 percent moisture content is ideal for pelletization because the steam generated by heat from the frictional rollers improves pellet integrity. The produced pellets can be used in biomass gasifiers or pellet stoves for producing heat and electricity. Gasification research at LSU has shown that biomass with high ash content is not ideal for gasification as a sole feedstock. However, blending high-ash wastes with biomass with low ash content (such as pine with less than 1 percent ash content) can improve the combustibility.



Figure 1. Incident solar radiation heats the solar still to very high temperatures (about 210 degrees F during midday). In the regular non-convection mode (with no air blower), water evaporated from the wet waste condenses on the cooler glass surface and runs to the bottom of a special channel to be drained out. In the convection drying mode (with air blower), water is carried away with incoming fresh air. This concept was validated in the Department of Biological and Agricultural Engineering using separated dairy manure in smaller, custom-built solar stills.

Chandra Theegala is a professor in the Department of Biological and Agricultural Engineering.



April Lovelady, a postdoctoral researcher with the LSU AgCenter Audubon Sugar Institute in St. Gabriel, conducts studies that focus on liquid-liquid separation to recover butanol from fermentation broth. Adding a saline solution to the broth creates a mixture of two layers, an alcohol-rich organic layer on top and a water-rich aqueous layer on bottom. Photo by A. Denise Attaway

Potential for Butanol Recovery from Fermentation Broths

April Lovelady

Louisiana grows sugarcane on more than 400,000 acres, producing 13 million tons of sugarcane annually. One ton of sugarcane yields as a byproduct, approximately 286 pounds of molasses. This is a production of 1.86 million tons of molasses per year. Molasses contains approximately 50-55 percent simple sugars—sucrose, fructose and glucose. The sugars found in molasses are ideal feedstocks for fermentation to a wide variety of products. The bacterium known as *Clostridium beijerinckii optonii* can produce butanol and isopropanol from these sugars. While isopropanol could be sold as a chemical commodity, butanol derived from the fermentation could be used to supplement the nation's fuel supply.

Butanol production from molasses fermentation can be used to produce acetone, butanol and ethanol. Batch fermentations using 5 percent sugarcane molasses have produced solutions of 1 percent butanol and 0.6 percent isopropanol, while continuous fermentations have produced solutions of 0.7 percent butanol and 0.5 percent isopropanol. Beyond lab-scale experiments, the challenge for commercial

production is removing butanol from the fermentation broth in a way that is economical and environmentally friendly. Butanol produced by fermentation can be used as a biofuel because it has an energy content near that of gasoline, and it can be used as a feedstock for other biofuels like biodiesel with blends of up to 16 percent possible. In addition, butanol is compatible with existing engines, storage and transportation infrastructures.

Conventional methods for removing butanol from fermentation broth include distillation and extraction. Distilling the butanol is costly and energy-intensive. Separating butanol from the fermentation broth by extraction requires adding a solvent to separate the butanol from the water in the broth, forming two layers, similar to what happens when oil is mixed with water. This is called liquid-liquid extraction, and the extracting solvent has to be removed from the mixture.

Research at the LSU AgCenter is focused on liquid-liquid separation by increasing the salinity of the solution to recover the butanol. Several salts are present in the fermentation media

as nutrients. A saline solution made from these salts and distilled water was added to model fermentation broths to determine its effectiveness at concentrating and separating the butanol from the broth. Model fermentation solutions were made by mixing butanol, isopropanol and distilled water. The butanol to isopropanol ratio in the model solutions was identical to that observed into actual fermentations. Adding the saline solution created a mixture made of two layers. The upper layer is the alcohol-rich, organic layer. The bottom layer is the water-rich, aqueous layer. Results from these experiments showed that higher salinities led to better butanol recovery.

Using molasses to produce butanol would create an additional market for blackstrap molasses. The current price for molasses in Louisiana is \$155 per ton, and selling molasses for biofuel production could increase the revenue of the currently \$288 million molasses market for Louisiana sugar producers.

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Louisiana's sugarcane crop has been taken in new directions to provide high-biomass, low-sugar versions for biofuels and bioproducts industries. See page 10

Sweet sorghum can be grown at different times than sugarcane but yet harvested and transported using the same equipment as sugarcane. See page 12

Louisiana, Mississippi and Arkansas have plenty of room to grow sweet sorghum and energycane yet not interfere with other crop production. See page 14

Carbonization can turn cottonwood and switchgrass into charcoal to be co-fired with coal as a renewable energy source. See page 20



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The Southern Region Offers

Major New Crops For Biofuels Development

Energycane and sweet sorghum provide year-round feedstock supply for biofuel and specialty chemical processing plants using existing infrastructure in the southern United States.

The Sustainable Bioproducts Initiative, known as SUBI, involves a team of researchers studying the production of biomass and sugars for economically viable conversion to bioproducts. The researchers are studying how energycane and sweet sorghum can be grown in Louisiana, Alabama, Arkansas, Florida, Georgia, Mississippi and Texas to help meet future bioproduct demands.



Energycane



Sweet Sorghum



For more information, visit www.LSUAgCenter.com/SUBI.

USDA-NIFA Award No.: 2011-69005-30515