

BioCentury Research Farm Update

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Introduction

The BioCentury Research Farm (BCRF) had a diversity of users in 2013. Iowa State University (ISU) faculty and staff from the Departments of Agricultural and Biosystems Engineering; Agronomy; Biochemistry, Biophysics, and Molecular Biology; Civil, Construction, and Environmental Engineering; and Food Science and Human Nutrition, as well as the Bioeconomy Institute (BEI), Center for Crops Utilization Research (CCUR), Center for Sustainable Environmental Technologies (CSET), College of Agriculture and Life Sciences, and Extension and Outreach conducted research, teaching, and/or outreach at the BCRF. Private industry users of the BCRF included AGCO, Avello Bioenergy, Deere & Company, Direvo Industrial Biotechnology, DuPont Cellulosic Ethanol, Frontline Bioenergy, Phillips 66, and Virent, Inc. By the end of 2013, the BCRF had over 100 full- and part-time users with projects in more than 95 percent of available space.

Research, Upgrades, and Equipment

A great deal of research project activity occurred at the BCRF in 2013. The major activities included the following areas:

- Algae research and production methods
- Biochar research
- Biochemical research that included distillation, fermentation, and related processes
- Biomass feedstock collection and logistics research
- Biomass feedstock preparation
- Biomass conversion to value-added products

- Infrastructure upgrades and equipment acquisition
- Thermochemical research that included biomass gasification and pyrolysis processes

Algae. Various production systems located in the BCRF Algae Facility are being used to grow algae including flat panel bioreactors, two raceway pond systems, a novel revolving biofilm reactor, and various lab-scale reactors. The researchers have the ability to produce 1.3 to 4.5 kilograms of dried algae biomass per week.

The facility is equipped with geothermal heating and cooling to allow for year-round cultivation and contamination control. It also has equipment to test pH, algae cell density and light intensity, as well as other equipment necessary to cultivate algae at this scale.

The lipid, protein, carbohydrate, and ash levels in the algae are analyzed, and fatty acid and amino acid profiles are measured and recorded.

The diverse algae species grown in the facility are suited for different end-uses. For example, algae with high lipid levels are good for producing biodiesel, and algae with high protein levels and good amino acid profiles are good animal or fish feed.

Biochar. Approximately 70 kilograms of biochar was applied to half of a 30-ft × 60-ft field plot located in the BCRF demonstration plot area called the “Plant Zoo.” Sorghum-sudangrass was planted in the plot to compare the yields of the treated and untreated areas and conduct postharvest soil tests.

Biochemical. Multiple biochemical projects were completed at the BCRF in 2013. These projects included fermentation and distillation work as well as corn ethanol process improvement.

One such project was focused on improving animal feed gained from the corn ethanol process. Direvo Industrial Biotechnology GmbH from Cologne, Germany, contracted with the CCUR and BCRF to test new enzymes and prepare three batches of modified distillers dried grains with solubles (DDGS). This pilot-scale production run tested the enzyme effects on corn ethanol distillation, liquid/solid decanting, liquid evaporation, and DDGS drying. The project also tested enzyme effects on DDGS composition and monogastric animal (i.e., chickens) feed efficiency. About 450 kilograms of modified DDGS were delivered to Direvo for the feeding studies. This is the third project for Direvo in a continuing collaboration with CCUR and BCRF.

Biomass feedstock collection. Multiple projects continued in this area in 2013 with the most notable ones related to the DuPont Cellulosic Ethanol (DCE) and POET-DSM Advanced Biofuels research support efforts led by Matt Darr and Stuart Birrell, professors, ISU Agricultural and Biosystems Engineering.

For the DCE project, 55,000+ acres were harvested to collect 110,000 tons of corn stover bales. This effort included a combination of the ISU stover harvest team, DCE harvest teams, and a custom harvest subcontractor. The BCRF received numerous bales for observation and ash content and moisture content sampling.

Agriculture product development and research support for several of the major agriculture equipment manufacturers continued throughout the entire year at the BCRF. New

Holland Agriculture provided ISU use of two tractors and a baler for the purpose of quantifying the efficiency and other parameters of one of its square baler models. The tractors will remain at the BCRF for general use purposes throughout 2014.

Biomass preparation. The BCRF prepared biomass feedstocks for several internal and external clients (e.g., universities, national laboratories). The farm's fine particle biomass preparation lab was used to fine grind, screen, and size the feedstocks. Approximately four tons of three-quarter-inch clean corn stover, two tons of quarter-inch pine, one ton each of 650 and 300 micron switchgrass, and one ton each of 650 and 300 micron clean corn stover were shipped to support the USDA-CAP project.

More feedstock was provided to the National Advanced Biofuels Consortium (NABC). The BCRF processed 2.8 tons of loblolly pine and 7.5 tons of corn stover. The ground feedstocks were sent to NABC members and used in various biofuels projects. This was the third year the BCRF supplied ground feedstocks to NABC. The NABC expressed its gratitude to ISU at its annual meeting for providing high quality feedstocks to its projects.

Biomass conversion to value added products. Projects to create new markets for perennial cover crops were done at the BCRF. Buddhi Lamsal, professor, ISU Food Science and Human Nutrition, and his research team used stripped alfalfa leaves to recover a high-value protein that could be made into value-added products such as a protein supplement for poultry and aquaculture feeds. The protein quality and its suitability as poultry or aquaculture feed were assessed. Lamsal's team also looked at the juice's whey fraction, the sugar-rich residual stream after removing the protein. They evaluated if the fraction would be a suitable fermentation feedstock for the

production of biochemicals such as polylactic acid and biosurfactant.

Infrastructure and equipment. A ventilation tower was constructed at BCRF to improve the ventilation when the Biomass Processing Facility lab fume hoods are used. The new ventilation system also will assist with a Department of Energy sponsored project led by BCRF affiliate Robert Brown, professor, ISU Mechanical Engineering. The tower was funded by ISU's "Leading the Bioeconomy" initiative supported by an appropriation from the Iowa Legislature.

A new membrane filtration system was installed in the biochemical processing train. The system will be used for cell separation of fermentation broths, protein purification, and other general operations requiring pilot-scale ultra filtration. The system features the ability to handle membrane cartridges 2.5, 4, and 8 inches in diameter, three onboard feed and recirculation pumps, and built-in flow meters. The Plant Sciences Institute provided funding for the system.

Thermochemical. The CSET started a new Department of Energy-sponsored bio-oil stabilization project with the goal to produce a stable bio-oil that could be integrated into an oil refinery and blended with traditional petroleum feedstocks to make hydrocarbon fuels. The fast pyrolysis process development unit, located in the BCRF thermochemical train, was used to convert biomass feedstocks into four distinct bio-oil fractions.

The fast pyrolysis unit also was used for bio-oil production using red oak and clean corn stover feedstocks for both internal and external projects. This work was done mainly to explore possible uses for individual fractions, including a path to fermentable sugars.

Upgrades to the pyrolysis process development unit were completed in 2013 and allowed the unit to produce up to six fractions and increased the pyrolyzer's processing rate from seven kilograms of biomass per hour to 10 kilograms per hour.

An ISU research team led by Robert Brown was awarded a patent for the fractioning process that the pyrolysis process development unit is based on. The technology has been exclusively licensed to Avello Bioenergy, Inc., an ISU graduate student's startup company located at the BCRF.

The gasifier has been used to support a student's doctoral research on using switchgrass feedstock. Work included exploration of the operational thresholds of the bubbling fluidized bed reactor and investigation of alternative methods for gasification tar analysis. CSET relocated a combustion unit from Black Engineering to burn the syngas as it is produced and made other improvements.

Grants, appropriations, and donations. From its inception in 2009 through 2013, BCRF has been well supported with private industry donations. To date, the following companies contributed monetary and/or in-kind support to ISU for use at the BCRF:

- AGCO Corporation
- Centocor, Inc. (Johnson & Johnson)
- Country Landscapes, Inc.
- Crown Iron Works Company
- Deere & Company
- DemoDozer, Inc.
- DuPont Cellulosic Ethanol (DCE)
- New Holland Agriculture
- Pioneer Hi-Bred International, Inc.
- Rockwell Automation, Inc.
- University of Northern Iowa National Ag-Based Lubricants Center
- Vermeer Corporation

Through these donations, BCRF has increased its capabilities in biomass harvesting, bulk storage, transport, preparation, fermentation, and production of bio-oil, syngas, and other products. These donations included construction of three large hoop sheds, grinding and sieving equipment, control systems and software, fermenters and bioreactors, other ancillary equipment, landscape enhancements, and unlimited use of several pieces of agricultural and industrial equipment.

ISU received a \$7.5 million appropriation from the Iowa Legislature to support ISU's "Leading the Bioeconomy" Initiative.

The initiative supported (and will continue to support) several CCUR and BCRF research projects:

- Development of specialized business organization and decision support tools to achieve the quality standards of corn stover supply chain end-users.
- Development of soil health and quality maintenance methods for the stover supply chain.
- Providing of data driven knowledge to help guide the growth and development of industrial biomass supply chains and the corn stover supply chain sector as a whole.
- Development of supply chain training sessions for Iowa small businesses and startup companies.
- Identification of additional support for supply chain solutions.
- Utilization of co-products from dry-grind corn ethanol plants to develop value-added products such as enhanced distillers' dried grains with solubles (DDGS) animal feed, ethanol, and biogas (methane).
- Development of a corn-soybean biorefinery concept where hazardous solvents are replaced with water to extract oil from soybeans. This method could provide

additional fermentable sugars to increase ethanol production, and improve the protein quality of DDGS and increase oil recovery for biodiesel.

- Fermentation of microalgae using by-products derived from biodiesel production or dry-grind corn ethanol production. Products from the microalgae fermentation can be used for high-value food or feed.
- Conducting of a planning meeting to recruit industry members for a proposed National Science Foundation Industry-University Cooperative Research Center for Bioplastics and Biocomposites and meet the NSF planning grant requirements for full implementation of the center.
- Commercialization of a product from an ISU Biopolymers & Biocomposites Research Team-related project.

Visitors and Tours

Information dissemination and promotion was accomplished through tours, conferences, and symposiums. Tours were provided for 110 groups with approximately 2,118 visitors in 2013. Since the dedication in 2009, the BCRF has hosted 497 tours with 7,651 visitors.

The 2013 tours included visits by Annie's Project, Centro de Tecnologia Canavieira from Brazil, Conservation Districts of Iowa, ELCA World Hunger Leadership Gathering, Farm Foundation Round Table, the Hebei Animal Husbandry Cooperation Delegation from China, Iowa Agriculture Development Authority, Iowa County Supervisors, Iowa National Guard, Iowa Soybean Association, the National Corn Growers Association, National Institute of Agriculture Research from Argentina, USDA, and the ISU Vice President for Economic Development.

Several companies and other organizations also visited including Adkins Energy LLC, AGCO Corporation, Battelle, BP, Catchlight, CenUSA Bioenergy, Chemical & Engineering

News, Davenport Dryer, Deere & Company DuPont, Exxon Mobile, East Coast Media Group, Monsanto, Mitsui Chemicals, New Holland Agriculture, Pioneer, Sentinel Transportation, the Total New Energies France, and Valent Biosciences.

The BCRF also gave numerous tours to students and teachers from K-12 schools around the state as well as Plants in Society summer workshop participants; students from the CBiRC, the Howard Hughes Medical Institute Scholars, and other Research Experience for Undergraduates programs; and students and professors from various universities.

Approximately 506 visitors were hosted by the Ames Visitors and Convention Bureau in 2013. There were 232 visitors who attended the Nationwide Insurance Field Days. The BCRF also hosted an open house for the completed Algal Greenhouse.

National reporters and photographers visited the BCRF as part of a four-day tour of Iowa. The tour was intended to give journalists a chance to see corn production and facilities making biofuels.

The BCRF was an exhibitor at the 2014 Iowa Renewable Fuels Summit and Trade Show on January 28 in Altoona, Iowa. Many attendees visited the exhibit and were able to see samples of materials produced at the BCRF including ground feedstocks, bio-oil, biochar, and torrefied corn stover pellets.

Through close cooperation with the ISU Research Farms, the Ames Convention and Visitors Bureau, the BEI, and the ISU Foundation, many public organizations, private companies, educational organizations, international organizations, and citizens of Iowa have visited the BCRF.