United States Department of Agriculture

Agricultural Research Service

Bioenergy and Energy Alternatives National Program Significant Accomplishments

Bioenergy research has been and continues to be an active, high priority for the Agricultural Research Service (ARS). Concerns over the security and reliability of our energy supply, compounded by the environmental effects of fossil energy use, the economic costs of importing petroleum, and a struggling rural economy have spurred interest to develop alternative, renewable energy.

ARS formed its Bioenergy and Energy Alternatives National Program (www.ars.usda.gov/biofuels) in 1998 to develop alternative energy sources, to reduce the Nation's dependence on foreign oil, and to improve the environment. The program also helps increase the use of agricultural materials as feedstocks for biofuels and products, creates jobs, and stimulates economic activity in the United States. This national program not only supports ARS priorities but also ensures that problems of high national priority are being addressed.

ARS works with a range of industry stakeholders, university, state and federal partners to conduct biofuels research.

The Cell Wall Initiative (CWI) at ARS specifically focuses on the production and enhancement of lignocellulose for conversion to ethanol.

The CWI is using genomics to understand and manipulate all the genes that control cell wall content and synthesis with the goal of developing biofuel crops with optimal ethanol conversion characteristics including developing and modifying biofeedstock (including modifying the plant cell wall) to produce maximum crop yield and superior quality. The program also provides technological support for the commercial production of cellulosic ethanol from agricultural crops.

Eco-friendly corn milling for ethanol production

ARS has developed a new process using enzymes to break down corn's starch and protein while reducing or eliminating the need for hazardous sulfur dioxide

during ethanol production. The new process could potentially lower costs and decrease production time. The enzymatic method produces yields equal to or better than the conventional process and adds value to the Dried Distillers' Grain coproduct. This patented process (U.S. Patent 6,566,125) has been successfully tested on a commercial scale; design and construction plans are now being developed to implement the process. ARS scientist David Johnston received a Presidential Young Scientist Award from the White House in 2006 for this work. An announcement of the licensing of this process to a major enzyme company is expected soon.

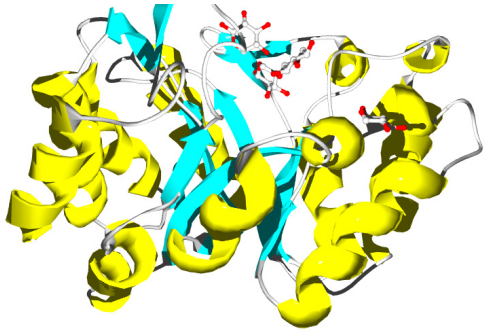
Improved cellulose processing for bioenergy

The National Center for Agricultural Utilization Research, Peoria, IL, is conducting research targeted at improving conversion of cellulose to ethanol. This includes developing new enzymes, microbes, and processes to enhance the breakdown of lignocellulose and developing pretreatment, saccharification, and fermentation processes for converting agricultural residues

such as wheat straw, rice hulls, and corn fiber to fuel ethanol.

Selected achievements:

- Discovered the most active xylosidase enzyme for releasing sugars from biomass
- Isolated and expressed fungal enzymes for biomass processing
- Developed new corn fiber biochemical treatment processes using fungal preparations
- Engineered bacteria capable of converting multiple sugars to ethanol
- Developed new pretreatment processing solutions for wheat straw with enhanced biomass processing
- Developed yeast strains that metabolize hydrolysis by-products which inhibit fermentation
- Discovered glucose-resistant ethanolic microorganisms capable of using multiple sugars
- Used *Lactobacillus plantarum* as a biocatalyst for ethanol production
- Developed an environmentally sensitive pretreatment process for lignocellulose biomass

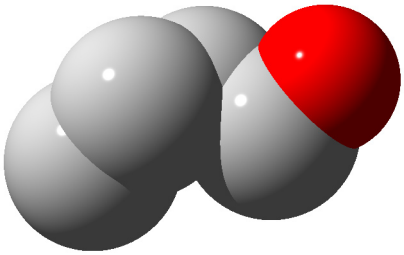


Enhanced ethanol–water separation

ARS researchers have identified solvents that are especially good at separating ethanol and water in fermentation broths either by themselves or in combination with membrane processes as alternatives to the energy-intensive distillation processes now being used. Optimizing this technology could significantly lower the cost of ethanol production and may lead to the development of continuous glucose fermentation, which would improve the efficiency of ethanol production even further.

Butanol from wheat straw

ARS scientists have developed a new way to produce butanol from wheat straw hydrolysate. Butanol can serve not only as fuel but also as a chemical feedstock. The fermentative bacterium efficiently uses multiple sugars that are present in the wheat straw hydolysate. In this new method, butanol can be recovered during fermentation, significantly reducing production costs.



New value-added coproducts from starch and cellulose processing

Developing high-value coproducts and bioproducts from starch and cellulosic biomass processing would improve the profitability of bioenergy production. Coproducts represent an important component to the successful commercialization of the biomass-to-ethanol industry and are potentially high revenue streams that may significantly improve the economics of both corn grain and cellulose processing. These products include enriched protein and fat products for livestock feed, high-value corn oil, phytosterols, and other valuable products such as sweeteners, adhesives, and environmentally sensitive materials.

Selected achievements:

- Develope simple, inexpensive methods to obtain enriched protein, starch, and fat from corn fiber and other biomaterials
- Developed a new biochemical process to extract greater than 90 percent of corn oil from distillers' dried grains
- Developed and optimized processes to produce "quick fiber" oil containing high-value products such as phytosterols
- Developed and optimized processes for continuous extraction of zein
- Discovered that oil from hull-less barley contains health-enhancing nutraceuticals
- Produced health-enhancing peptides from corn germ
- Produced high-value sweetener via recombinant bacteria
- Identified potential biobased adhesive coproduct of biomass processing

Lower cost biodiesel processing

Researchers at the ARS Eastern Regional Research Center (ERRC) in Wyndmoor, PA, have developed conversion technology to produce biodiesel from low-cost, agricultural feedstock such as tallow, greases, soapstock, and lipid-bearing materials such as intact soy flakes, DDGs, meat and bone meal.

Specifically, ARS has

- Developed novel methodology to produce biodiesel from waste soapstock
- Developed robust technical cost models for biodiesel production processes
- Developed a new method for biodiesel production from acid oil, which has been adopted by private industry
- Developed and demonstrated in situ production of biodiesel from oilseeds
- Developed an immobilized enzyme bioreactor for biodiesel production
- Developed new processes to convert waste cooking oil to biodiesel and partnered with private industry for demonstration of these methods
- Begun to develop methods with private industry to eliminate hexane use in biodiesel processing

New value-added coproducts from biodiesel

Biodiesel processing offers numerous opportunities for the introduction of novel chemistry to create value-added coproducts that can significantly improve the economics of biodiesel production. ARS scientists at ERRC have a strong tradition of research on non-food, agriculturally derived coproducts and have had continued success in applying this tradition to the conversion of lipid-bearing materials into valuable, environmentally sensitive commercial products.

ARS scientists at ERRC have improved:

- Utilization of glycerol for production of bioplastics
- Processes for direct conversion of fats and oils to energy
- Creation of glycerol-based polymers for potential new uses

Energy alternatives for rural practices

ARS scientists in Bushland, TX, have developed and evaluated remote, off-grid wind- and solar-powered water pumping systems for irrigation, livestock, and farmstead water and developed electric generation systems for rural and remote areas.

New bioenergy crops

Development of dedicated energy crops through traditional and molecular breeding presents profound opportunities for improving the suitainable yield of biomass and enhancing the efficiency of conversion. ARS research includes identifying genes involved in cell wall biosynthesis and the manipulation of these genes at the genomic or cellular level for enhanced cell wall digestibility and decreased lignin content. Research in this area also includes evaluating various crops for suitability and sustainability based on eco-region, genetic variation, and production economics.

Selected achievements:

- Conducted a survey of biomass feedstocks and their digestibility based on plant type and maturity
- Developed lower lignin content sorghum
- Developed a non-lodging, biomass-type of alfalfa that can provide high yields of alfalfa leaves and stems
- Identified *Medicago truncatula* as a good model plant for legume research
- Determined genetic sequences of Brachypodium, a model for bioenergy grasses
- Assessed average biomass yield from conservation grasslands
- Evaluated seasonal variations of switchgrass on thermochemical conversion
- Conducted a greenhouse-gas life cycle assessment of bioenergy crops grown in the Northeastern United States
- Identified and characterized a maize mutant with reduced lignin in plant leaves
- Determined the economic production cost feasibility of perennial herbaceous energy crops
- Characterized and analyzed the switchgrass genome

- Began developing energy cane for increased biomass yields
- Developed basic molecular genetic information for the genetic mapping and modification of switchgrass
- Modified the genetics of switchgrass to enhance energy crop properties

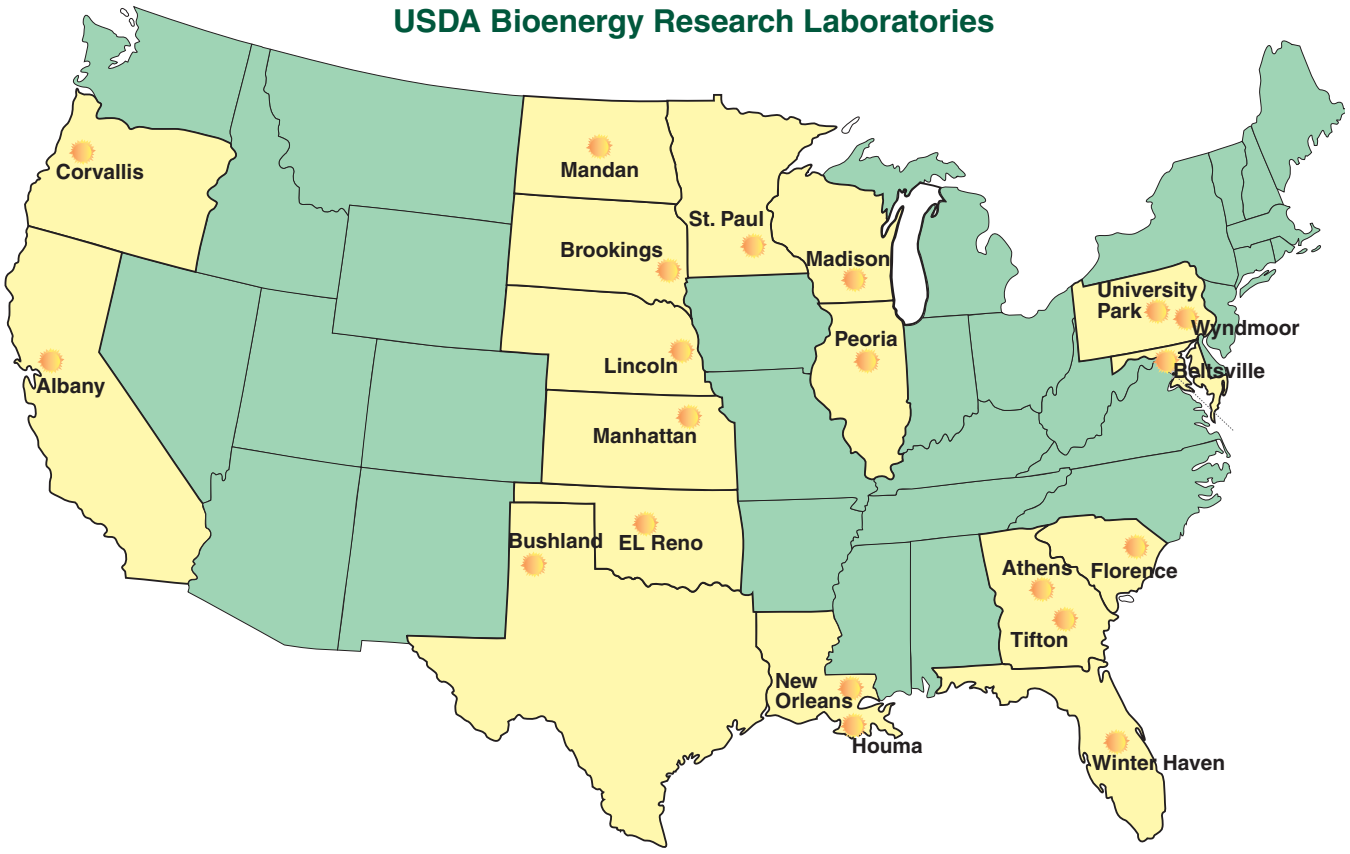
Sustainable crop production

Crop residues have long been considered as abundant bioenergy sources with the assumption that there will be little or no deleterious production or environmental effects from residue removal. A long-term field study by ARS in eastern Nebraska to evaluate the impact of stover harvested for biomass energy on soil and productivity established the importance of crop residue biomass in soil integrity and fertility. Corn stover removal for bioenergy production will require precise management to ensure sustainable productions.

Contact information

Robert Fireovid, PhD
Robert.Fireovid@ars.usda.gov
301-504-4774

USDA Bioenergy Research Laboratories



August 2007