USDA-ARS NATIONAL PROGRAM FOR BIOREFINING RESEARCH

FY2013 Annual Report

The ARS Biorefining Program enables new commercially-viable technologies to (1) convert agricultural materials and byproducts into fuels and other marketable products, and (2) reduce risks and increase profitability in existing industrial biorefineries. Whenever possible, research under the Biorefining Program is coordinated with research in the USDA Regional Biomass Research Centers, which accelerate the creation and integration of regional bioenergy supply chains into existing agricultural production systems. The current Action Plan for the Biorefining National Program has the following three Components:

- Biochemical conversion
- Biodiesel
- Pyrolysis

SELECTED ACCOMPLISHMENTS

Biochemical Conversion

- **Controlling bacterial contaminations without antibiotics.** Lactic acid bacteria frequently contaminate commercial fuel ethanol fermentations, reducing yields and decreasing biorefining profitability. Current practice to control these bacterial contaminations involves antibiotics, but there is concern about the fate of these antibiotics in waste water and ethanol co-products used in livestock feed. ARS researchers in Peoria, Illinois, and Beltsville, Maryland, discovered antibacterial enzymes called phage endolysins that inhibit lactobacilli; and they expressed the genes for endolysins in ethanol-producing yeast, thus reducing the need for antibiotics in fermentation. ARS has applied for a patent for this technology, which ethanol biorefineries can use to prevent bacterial contaminations and avoid large scale antibiotic use.

- **Removing cellulase inhibitors from pretreated biomass.** The most expensive step in converting biomass to fuels involves the use of cellulase enzymes to hydrolyze cellulosic biomass to fermentable sugars. One of the reasons for this high cost is that byproducts produced by pretreating cellulosic biomass significantly inhibit cellulase enzymes. ARS scientists in Peoria, Illinois, developed a low-waste fermentation process to remove these enzyme inhibitors and showed, in collaboration with Purdue University, that this biological conditioning or 'bioabatement' process increases conversion of cellulose to fermentable sugars by 20-50%.

- **Identifying best switchgrass variety for biorefining.** Switchgrass, a perennial grass native to the Midwest prairies, has significant potential as a bioenergy crop because of its high biomass yields. Although upland switchgrass is preferred for forage applications because it is more digestible by ruminant livestock (e.g. cattle), lowland switchgrass gives higher biomass yields. ARS scientists in

Peoria, Illinois, determined that the lowland variety yielded as much or more ethanol per pound switchgrass than the upland variety when it is harvested post-frost. This result shows that the lowland variety is a preferred biorefining feedstock if it is harvested at the right time.

- **Enzymes for preprocessing biomass.** Breaking the chemical crosslinks between lignin and carbohydrate fibers greatly improves the value of biomass for biorefining or in livestock feed. Using genomic techniques, ARS scientists at Albany, California, discovered a new feruloyl esterase enzyme that eliminates these crosslinks, thus facilitating the digestion of biomass. They expressed the enzyme in *E. coli*, a bacteria used to produce enzymes at industrial levels, and confirmed the enzyme's effectiveness when applied to rice bran, wheat bran, corn fiber, switchgrass, and corn bran (in order of decreasing activity). A patent application was filed and an industrial partner is considering using the technology to produce livestock feed.

- **Enabling the production of cellulosic ethanol.** Chemical byproducts from the pretreatment of biomass for conversion to fuels or chemicals decrease process efficiency and increase costs because they significantly inhibit the growth and productivity of the yeast necessary to ferment the biomass. To overcome this inhibition, ARS scientists in Peoria, Illinois, developed inhibitor-tolerant yeast strains and optimized fermentation process conditions such as temperature, pH and media composition. They found that the right process conditions increased the volumetric ethanol productivity 2.5-fold to 10-fold and increased the ethanol yield 1.5-fold to 10-fold, depending on yeast strain.

- **Activated biochar improves cellulosic ethanol production.** Chemical byproducts from the pretreatment of biomass for conversion to fuels or chemicals decrease process efficiency and increase costs because they significantly inhibit the growth and productivity of the yeast that ferment the biomass. Although these inhibitory byproducts can be removed by increasing the pH of pretreated biomass to ~ 10, removing the solids, and then reducing the pH to 5-6, these additional steps add significant material and processing costs. ARS scientists in New Orleans, Louisiana, and Peoria, Illinois, showed that adding activated biochar to the pretreated slurry resulted in absorption of the inhibitors and allowed the fermentation to proceed normally without a solids-removal step.

Pyrolysis

- **Low-cost process for producing marketable pyrolysis oil.** Pyrolysis converts biomass into bio-oil, a petroleum-like liquid which could potentially be refined into a renewable, drop-in replacement for petroleum-based fuels. However, bio-oil cannot be used by existing petroleum refiners because it contains too much oxygen. Although oxygen can be removed from bio-oil by catalytic reaction with oxygen, , this hydrotreating is expensive and reduces product yield. ARS researchers in Wyndmoor, Pennsylvania, developed and are patenting a relatively simple non-catalytic process utilizing tail gas from the pyrolysis reactor to reduce the oxygen content of the bio-oil from 35% to 12%. The new process doubles the yield of distillate product and yields a more narrow range of products (5-10 compounds) vs. traditional pyrolysis (hundreds of compounds).