Quarterly Update

National Bioenergy Center Biochemical Platform Integration Project

Biomass

Biomass Program—Sustainable Fuels, Chemicals, Materials, and Power

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The Biochemical Process Integration Task focuses on integrating the processing steps involved in enzyme-based lignocellulose conversion technology. This project supports the U.S. Department of Energy's efforts to foster development, demonstration, and deployment of "biochemical platform" biorefineries that economically produce commodity sugars and fuel ethanol, as well as a variety of other fuel and chemical products, from abundant renewable lignocellulosic biomass.

The National Renewable Energy Laboratory manages this project for DOE's Office of the Biomass Program. Information on the Biomass Program is available at Biomass Program.

To discuss the contents of this update, or for further information on the Biochemical Process Integration Task, contact Dan Schell at NREL, phone (303) 384-6869, email dan.schell@nrel.gov

R&D Progress

Progress on Understanding and Improving Sugar Measurements in Biomass Hydrolysates

We have two ongoing projects to (1) understand the accuracy of measuring soluble sugars in pretreated liquors and (2) improve the speed and accuracy of these measurements. We recently investigated the accuracy of measuring sugar concentrations in the liquor fraction of dilute-acid pretreated corn stover. Historically, uncertainty values have not been rigorously determined; instead a blanket 95% confidence interval estimate of ± 1.0%–2.0% of the measured value was assumed to apply to glucose and xylose measurements. To obtain a better uncertainty estimate, seven analysts performed multiple measurements of sugar concentrations in a single hydrolysate liquor sample, generating a total of 45 measurements. Statistical analyses of these results indicate that while analysts are able to accurately replicate their own measurements, larger variations occur between different analysts. The 95% confidence interval estimates for total glucose and xylose concentrations (sum of monomers and oligomers) were ± 1.0% for each compound for a single analyst. However, these estimates increased to ± 3.6% and ± 4.8%, respectively, when all analysts were considered. We also detected an unexpected correlation between the concentration measurement and the fractional dilution of the sample prior to analysis by High Performance Liquid Chromatography (HPLC). Clearly, accurate sugar concentration measurements are more challenging than previously thought, and we are continuing our efforts to further understand these issues to improve method accuracy and reduce measurement uncertainty.

In addition, current methods for HPLC analysis of monosaccharides require long analysis times (e.g., >45 minutes/sample). Technical advances in HPLC methods have been slow and incremental. Under subcontract to NREL, a research group at Baylor University devised a new ion chromatography method to analyze biomass-derived sugars. Their approach relies on a commercially available anion-exchange column and pulsed amperometric detection. Preliminary results with this new method show that it enables isocratic elution of all biomass sugars in approximately 5 minutes. We plan to further test, validate, and report on this method in the near future.

Expansion of the DOE/NREL Biochemical Pilot Plant

To achieve commercial-scale production of cost-competitive cellulosic ethanol, it is crucial to understand the entire biorefining process and how each process step impacts the performance of others. With the expansion of NREL's current biochemical pilot plant, scheduled for operational readiness in the fall of 2010, the cellulosic fuel industry will have access to a facility with considerably greater flexibility than previously available.

Drawing: M.A. Mortenson Company

Figure 1. The new pilot plant facility (dark gray) is sited in front of the older pilot plant building (left side of drawing). The new offices and conference rooms (dark red building) will be completed in September 2011 along with the addition of a second process train.

This new facility will add approximately 26,500 ft^2 of new processing area to the existing 8,000 ft^2 pilot plant (see Figure 1). The new building has a basement (9,800 ft^2) for feedstock storage, milling and handling; an open high bay (10,000 ft^2) with a control room and support laboratory; and a mezzanine (6,700 ft^2) around the exterior of the high bay. The Stage I portion of this project, scheduled for major completion in July 2010, includes the new pilot plant building and a one dry ton/d process train that includes equipment for feedstock handling through enzymatic hydrolysis. Stage II, scheduled for completion in September 2011, includes a second process train (with space still remaining for a third), new offices and conference rooms, and modification of supportive laboratory space.

When operating, feedstock is conveyed to a point nearly 50 feet above the high-bay basement elevation to a new pretreatment reactor system (see Figure 2). Pretreated material then flows by gravity to other unit operations. The new pretreatment reactor system is able to handle a wide range of chemicals, temperatures, and residence times. New mixers (see Figure 3) have been purchased to perform high-solids enzymatic hydrolysis. After initial liquefaction of the pretreated solids in the mixer, the material is pumped to a stirred tank reactor to complete enzymatic hydrolysis. The resulting sugar solution is sent to fermentors (1500-L and 9000-L vessels) in the older section of the pilot plant. Additional equipment and unit operations available in the pilot plant are: solid-liquid separators; an evaporator; continuous sterilizer; cross-flow filtration system; and product recovery by distillation. We will also have several smaller scale pretreatment systems as well as other fermentation systems ranging in size from 15 to 150 L.

Credit: Dan Schell

Figure 2. The one dry ton/d pretreatment system consisting of four horizontal tube reactors of varying sizes and residence times (two large tubes and one smaller tube are visible) and a flash tank (bottom of picture). Feedstock is pneumatically conveyed from the basement to the cyclone (top left of picture), weighed, and then fed to the reactor's pressure feeder.

The new facility will provide enhanced flexibility to perform integrated processing with a broad range of equipment options and configurations. The plant will be highly instrumented so that yield, mass, and energy balance calculations can be performed; and process samples will be analyzed using our standard, publicly available compositional analysis methods. Open space will remain after completion of Stage II so there will be room available to install new equipment or to support testing of industry-supplied equipment in a “plug and play” fashion.

Credit: Dan Schell

Figure 3. One of two Stage I mixers for high-solids enzymatic hydrolysis. Each jacketed vessel has distribution headers for enzymes, chemicals, and water.

Biochemical Process Integration Task Information

Web-based information on the process integration project, including presentations made at past review meetings, are available at the following links: http://obpreview07.govtools.us/biochem/ and http://www.obpreview2009.govtools.us/biochem).

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