Quarterly Update

National Bioenergy Center Biochemical Platform Integration Project

Biomass

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

April-June 2009, #23

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

Evaluating Integrated Biomass-to-Ethanol Process Performance with Different Enzymes and Microorganisms

Achieving high conversion of biomass-derived sugars to ethanol yield is critical to realizing the DOE Biomass Program's 2012 target of cost-competitive cellulosic ethanol. To support this effort, we recently completed work to access integrated process performance by mimicking the process configuration published in the 2002 design report (Aden et al. 2002[†]) using various enzyme, fermentative microorganism, and total solids loading combinations. We performed enzymatic cellulose hydrolysis on dilute-acid pretreated corn stover using either Genencor's GC220 or an advanced enzyme (Enz. X) at a total solids loading of 17.5% or 20% (w/w). Then the sugars were fermented to ethanol using two glucose-xylose co-fermenting microorganisms, *Zymomonas mobilis* 8b and a proprietary adapted microorganism (Microorganism Y). The hydrolysate liquor was conditioned using an ammonium hydroxide-based process described in a previous newsletter (Vol. 21).

The cellulose-to-monomeric glucose and xylose-to-ethanol yield at various conditions are shown in Figure 1. The xylose-to-ethanol yield is calculated from the ethanol concentration in solution after subtracting ethanol produced from glucose, assuming a glucose-to-ethanol yield of 95% of theroretical. Cellulose-to-glucose yield with GC220 is 5-10% higher at 17.5% solids than at 20% solids, while Enzyme X is relatively insensitive to solids loading in this limited range (data not shown). We also found that, regardless of the operating conditions, ethanol titers remained in the range of 50-55 g/L. When initial glucose concentrations produced during enzymatic cellulose hydrolysis were lower, for example at the lower solids loading, xylose-to-ethanol yields were higher. This finding suggests that ethanol concentration is limiting conversion of xylose to ethanol.

[†]Aden, A., Ruth, M., Ibsen, K., Jechura, J., Neeves, K., Sheehan, J., Wallace, B., Montague, L., Slayton, A., Lukas, J. (2002) "Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover." Report No. NREL/TP-510-32438. National Renewable Energy Laboratory, Golden, CO, http://www.nrel.gov/docs/fy02osti/32438.pdf.

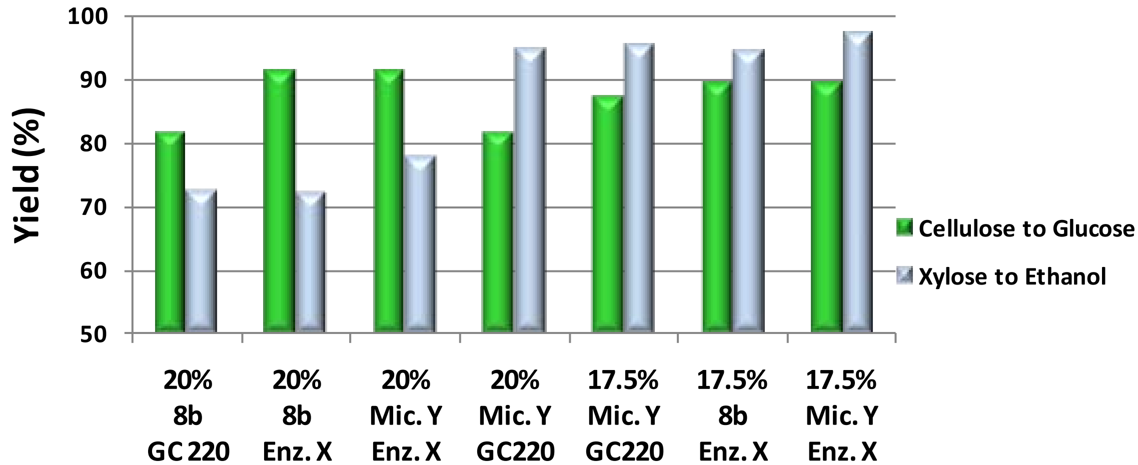

Figure 1. Cellulose-to-monomeric glucose yields during enzymatic hydrolysis and xylose-to-ethanol yields during fermentation of dilute acid pretreated corn stover with various enzyme microorganism combinations and at 17.5% and 20% total solids loadings.

Rapid Compositional Analysis of Feedstocks and Intermediate Lignocellulosic Process Streams

We use rapid calibration models to predict the composition of a variety of biomass feedstocks by correlating near-infrared (NIR) spectroscopic data to compositional data produced using traditional wet chemical analysis techniques (see Figure 2). The rapid calibration models are developed using multivariate statistical analyses of spectroscopic and wet chemical data. In an article to be published shortly in a special issue of the journal *Cellulose* (Wolfrum and Sluiter 2009*, available online), we discuss the latest versions of the NIR calibration models for corn stover feedstock and dilute-acid pretreated corn stover. Measures of the calibration precision and uncertainty are presented. This paper also compares two common algorithms for building NIR calibration models. No statistically significant differences (p=0.05) were seen using the different algorithms for the major constituents glucan, xylan, and lignin, but the algorithms did produce different predictions for total extractives. A single calibration model combining the corn stover feedstock and dilute-acid pretreated corn stover samples gave less satisfactory predictions than separate models.

Development of real-time (on-line) compositional analysis of intermediate process streams should enhance the biomass industry's ability to implement real-time process control and quality monitoring. We believe a continued focus on developing spectroscopy-based methods for real-time analysis is the preferred direction to take in the future, since a review of the pertinent literatures suggests these techniques are feasible to implement on-line.

*Wolfrum, E.J., Sluiter, A.D. (2009) "Improved multivariate calibration models for corn stover feedstocks and dilute-acid pretreated corn stover," Cellulose 16(4), pp. 567-576, DOI 10.1007/s10570-009-9320-2.

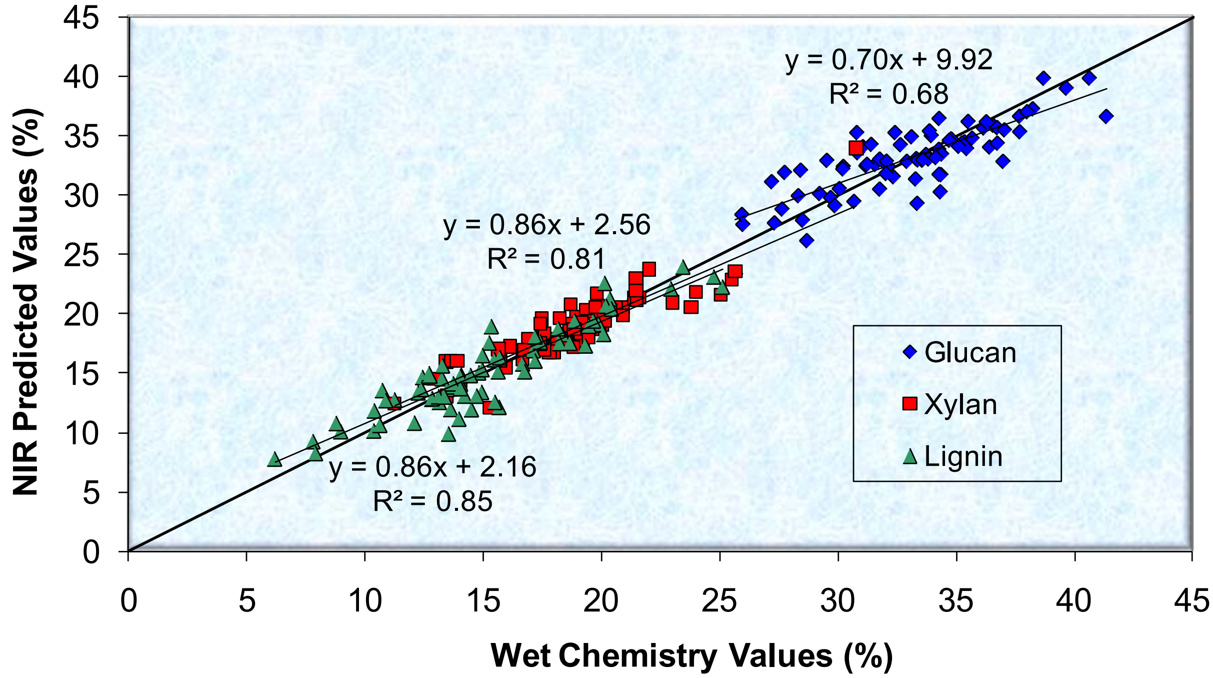

Figure 2. Predicted versus measured glucan, xylan, and lignin content for 77 calibration samples in a corn stover calibration model.

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. A discussion of how Stage Gate management is used in the Biomass Program is also available at this site (Stage Gate Management).

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