Quarterly Update
National Bioenergy Center Biochemical Platform Integration Project
Biomass

January - March 2009, #22

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

31st Symposium on Biotechnology for Fuels and Chemicals

The next Symposium will be held at the Intercontinental Hotel in San Francisco, CA, May 3-6, 2009. Meeting information can be found at the following web site: http://www.simhq.org/meetings/sbfc2009/index.html. A list of the technical session topics is as follows:

Sunday, May 3
Session 1 – Plant Science and Technology
Session 2 – Microbial Science and Technology I
Poster Session, Part 1

Monday, May 4
Session 3 – Biomass Pretreatment and Fractionation
Session 4 – Translational Genomics for Bioenergy Feedstocks
Session 5 – Enzyme Science and Technology I
Session 6 – Microbial Science and Technology II
Poster Session, Part 2

Tuesday, May 5
Session 7 – Biorefinery Deployment
Session 8 – Biofuels Logistics and Sustainability
Evening Special Topics:
Topic A: International Commercialization of 2nd Generation Biofuels
Topic B: Development and Commercialization of Algal-Based Biofuels

Wednesday, May 6
Session 9 – Bioprocessing and Separations Technology
Session 10 – Enzyme Science and Technology II
Session 11 – Emerging Biofuels and Chemicals
Session 12 – Biomass Recalcitrance

Seven poster or oral presentations will be delivered by Biochemical Process Integration project members covering integrated biomass processing performance, impact of corn stover variability on process performance, impact of solids loading on process economics, and biomass compositional analysis techniques.

R&D Progress

Evaluating Integrated Biomass-to-Ethanol Process Performance

A high overall ethanol yield from biomass is critical to achieving the DOE Biomass Program's 2012 target of cost-competitive cellulosic ethanol. Currently, significant improvements in the yield of ethanol from sugars produced from pretreated biomass are required to reach the conversion target of 90 gal/tonne. Although steady progress has been made over the years (see Figure 1), significant improvement in conversion yields are needed to meet the 2012 goals. In October 2008, we achieved an ethanol yield of 66.6 gal/tonne from dilute-acid-pretreated corn stover – the highest ethanol yield we have demonstrated from an integrated process to date. This work used the process design described in the 2002 design report (Aden *et al*. 2002). For the experimental runs, we used Genencor's GC220 enzyme for enzymatic cellulose hydrolysis and the glucose-xylose co-fermenting bacteria, *Zymomonas mobilis* 8b, to ferment corn stover-derived sugars to ethanol. The hydrolysate liquor was conditioned using an ammonium hydroxide process described in the last newsletter (Vol. 21). We then performed additional runs to improve conversion yields using various combinations of enzymes (GC220 and a new advanced enzyme preparation) and engineered microorganisms. The best combination produced an ethanol yield of 72.7 gal/tonne, a 9.2% improvement over the ethanol yield achieved in October 2008. Other combinations also produced yields in excess of 70 gal/tonne (data not shown).

Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallace, L. Montague, A. Slayton, J. 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.

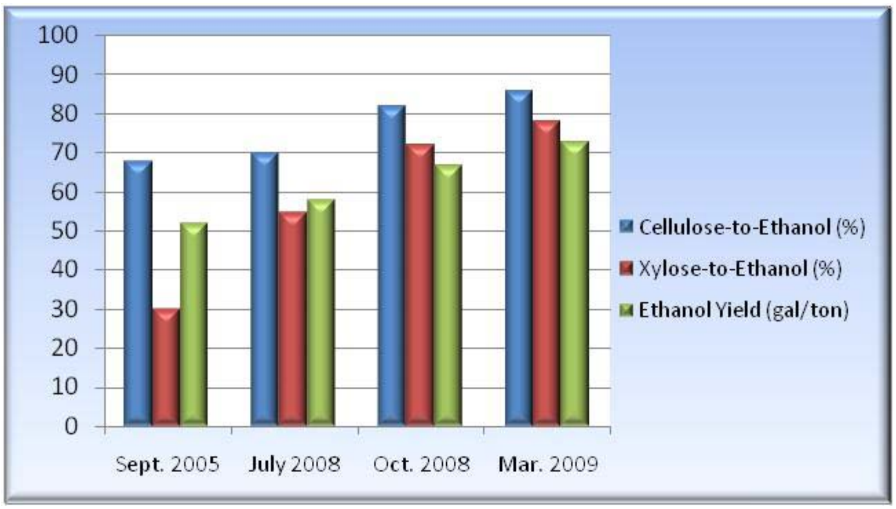

Figure 1. History of conversion yield improvement achieved for a process based on the 2002 design report (Aden *et al*. 2002)

Understanding the Accuracy of Lignocellulose Biomass Compositional Analysis Techniques

A complete compositional analysis of lignocellulosic biomass requires several wet chemical analytical procedures including water and ethanol extraction of soluble compounds and two-stage acid hydrolysis. It also requires multiple sample handling steps including vacuum filtration of residual solids remaining after acid hydrolysis, drying of these solids and preparing hydrolysate liquor samples for HPLC analysis. The carbohydrate content of the biomass sample is determined from the measurement of sugars in the hydrolysate liquor sample. However, sugars also degrade to by-products during the dilute acid hydrolysis step and so pure sugars standards (called sugar recovery standards [SRS]) are processed in parallel and used to correct for these losses. The overall process introduces many opportunities for errors that affect the overall accuracy of the analysis. In a first-of-a-kind effort at NREL to understand the magnitude of intra-laboratory errors in biomass compositional analysis, we designed a study to determine analysis errors by using multiple chemical analysts performing identical sample analysis in different laboratories at NREL. The composition of a single corn stover sample was measured multiple times by 8 chemical analysts in two different laboratories.

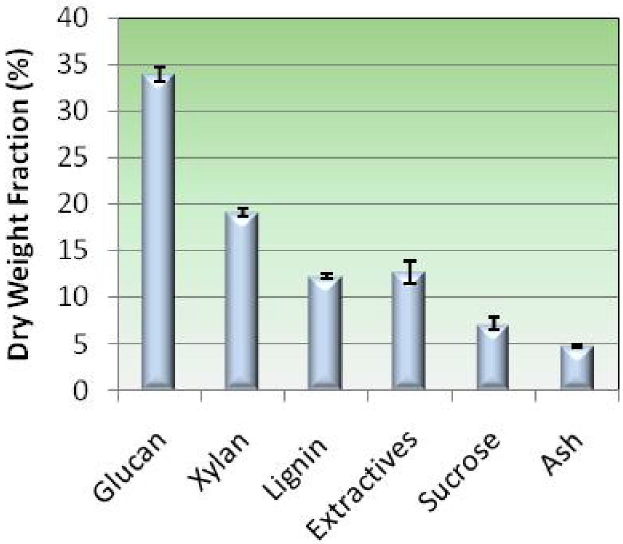

Figure 2. Average composition of a corn stover sample measured by 8 chemical analysts (not all components are presented). Error bars represent ± two standard deviations. Extractive excludes sucrose, which is reported separately.

The average composition of the corn stover sample with ± two standard deviation error bars are presented in Figure 2. An outlier test was used to remove suspicious data points. A cause for almost all unusual results was indentified, such as inconsistent performance during the water extraction step, unusual SRS values, and hydrolysate samples unintentionally concentrated during vacuum filtration. The coefficient of variation (CV, mean value divided by the standard deviation) for the major components glucan, xylan and lignin was 1%. Nevertheless, even our experienced analysts occasionally obtained significantly different results. We are working to specifically identify the root cause of all of the unusual results to better ensure a 1% or better CV level of confidence in the analysis results.

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 (Process Integration Project Information, http://obpreview07.govtools.us/biochem/, 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).

Produced for the
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1000 Independence Avenue, SW, Washington, DC 20585

Prepared by NREL, a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

DOE/GO-102009-2749 • April 2009

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% post consumer waste.