Quarterly Update

National Bioenergy Center Biochemical Platform Integration Project

Biomass

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

October-December 2007, #17

The Biochemical Processing 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 produce inexpensive 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 content of this update or for further information on the Biochemical Processing Integration Task, contact Daniel Schell at NREL, phone (303) 384-6869, email dan_schell@nrel.gov

30th Symposium on Biotechnology for Fuels and Chemicals

The Symposium will be held at the Astor Crowne Plaza Hotel in New Orleans, LA, from May 4-7, 2008. Meeting information can be found at the following web site: **http://www.simhq.org/meetings/30symp/index.html**. Session titles are listed below.

Sunday, May 4
Session 1 - Advances in Bioenergy Feedstocks and Plant Science
Session 2 - Advances in Microbial Science and Technology I

Monday, May 5
Session 3 - Pretreatment and Biomass Recalcitrance: Fundamentals and Progress I
Session 4 - New Biofuels and Biomass Chemicals
Session 5 - Advances in Enzyme Science and Technology 1
Session 6 - The New Biofuels Industry: Biomass Availability and Supply Chain

Tuesday, May 6
Session 7 - Advances in Microbial Science and Technology II
Session 8 - Pretreatment and Biomass Recalcitrance: Fundamentals and Progress II
Evening Special Topic: International Bioenergy Centers: Plans for the Future

Wednesday, May 7
Session 9 - Advances in Bioprocessing and Related Separations Technology
Session 10 - The New Biofuels Industry: Biomass Environmental Feasibility and Sustainability
Session 11 - Bioefining Technology Deployment and Demonstration
Session 12 - Advances in Enzyme Science and Technology II

Please note: Due to limited poster space, the symposium organizers are requesting that at least one author on each abstract be registered to attend the Symposium before the end of pre-registration. Also, if a paper is to be submitted for the Proceedings, at least one author must be registered and attend the Symposium.

R&D Progress

Economic Analysis Completed on Several Process Configurations for Converting Corn Stover to Ethanol We recently completed an economic evaluation of several process configurations for producing ethanol from corn stover using the methodology presented in previous work (Aden *et al*. 2002) and performance data we produced over the last few months. In the first configuration, cellulose in a whole slurry hydrolysate was enzymatically hydrolyzed to glucose in the presence of pretreatment liquors containing hemicellulosic sugars, and then all of the sugars were fermented to ethanol by a recombinant glucose-xylose co-fermenting *Z. mobilis*. In the second process configuration, pretreated solids and liquor were separated and the hemicellulosic sugars in the liquor were fermented using *Z. mobilis*, and independently, the cellulosic solids were enzymatically hydrolyzed to glucose and then the glucose was fermented by *Saccharomyces cerevisiae* using a simultaneous saccharification and fermentation process. Ethanol yields for

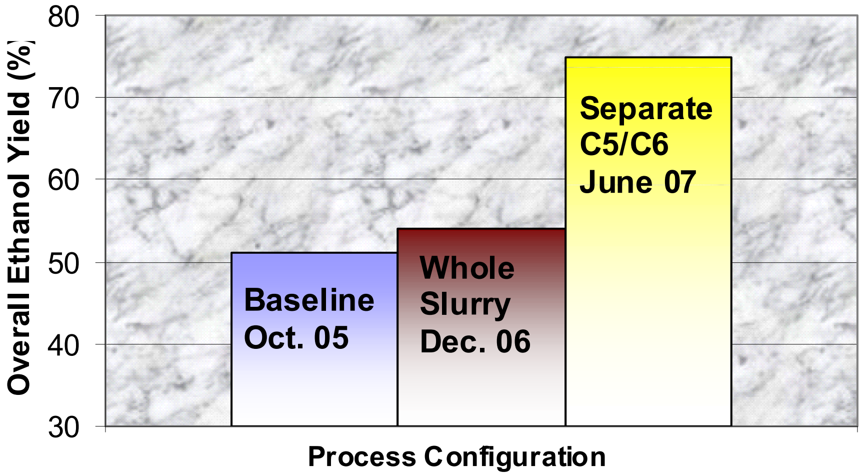

Figure 1. Ethanol yields from glucose and xylose achieved upon integrated processing using the baseline process configuration described in Aden *et al.* (2002)[†] and those described in text.

each of these configurations are shown in Figure 1. An ammonium hydroxide conditioning process was used on either the whole slurry or the separated liquor. The analysis showed that while the separate fermentation process configuration produced higher ethanol yields, the whole slurry configuration operating at 10% total solids produced a lower ethanol selling price — \$2.39 per gallon for whole slurry compared to \$2.55 per gallon for the separated process. This unexpected result was achieved by eliminating the expensive solid-liquid separation equipment in the whole slurry process configuration.

[†]Aden, A, M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallace. 2002. "Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover." National Renewable Energy Laboratory. NREL/TP-510-32438. http://devafdc.nrel.gov/bcfc/oraclefind3.cgi?6483.

Determining Factors that Affect Measurement of Lignin/Protein in Pretreated Herbaceous Feedstocks We recently determined that conventional wet chemical techniques for measuring Klason lignin do not correctly measure lignin in pretreated herbaceous materials. Since then, we have focused on exploring different hypotheses to identify factors that are causing abnormally high lignin measurements. The goal is to develop analytical methods that improve lignin and protein measurements in stover as well as other agricultural and herbaceous feedstocks (switchgrass, wheat straw, etc.). Previous work attempted to isolate and characterize the non-lignin-related insoluble material that was giving rise to the abnormally high Klason lignin values in pretreated materials. Klason lignin was isolated from corn stover using an organosolv or dilute-acid pretreatment process at varying degrees of pretreatment severity, and then the treated material was bleached using a standard acid chlorite process to remove lignin, leaving a non-lignin residue. This residue was characterized using solid-state NMR spectroscopy and elemental analysis to identify possible non-lignin compounds. For all pretreatment conditions, the weight of the residue material did not account for the abnormally high lignin measurements. We also showed that contamination by protein, carbohydrates, or waxy materials was not responsible for the high lignin measurements. This year, we will investigate whether sugars in biomass extractives (not accounted for in the analysis of the pretreated materials) may be rapidly degrading and forming polymers that contribute to the insoluble residue remaining after the Klason lignin procedure.

Related Activities

Paper Published in Biotechnology and Bioengineering NREL authors recently published a paper in the journal *Biotechnology and Bioengineering* (Volume 98, Issue 1, 112-122) OSTI ID: 915669. The paper, "Cellulase Digestibility of Pretreated Biomass is Limited by Cellulose Accessibility," was co-authored by Tina Jeoh, Claudia I. Ishizawa, Mark F. Davis, Michael E. Himmel, William S. Adney, and David K. Johnson. This paper is part of the work being performed in NREL's Targeted Conversion Research Task that is aimed at increasing understanding of the chemical and physical factors governing biomass recalcitrance to enzymatic deconstruction. A key technical barrier to commercializing fuels and chemicals from biomass is the high cost and relative inefficiency of producing fermentable sugars from lignocellulosics. Although pretreatment is commonly used to improve biomass conversion efficiency, questions remain as to how specific chemical or physical alterations of biomass conferred by pretreatment impact enzyme saccharification efficiency. Jeoh and co-workers report on a method to assess the cellulase accessibility of biomass by directly measuring cellulase binding and activity on pretreated substrates. The method uses a fluorescence-labeled purified cellobiohydrolase (Cel7A) isolated from a commercial *Trichoderma reesei* preparation. Using this method, they found that substrate drying decreased enzyme binding and digestibility, whereas removing xylan and decreasing cellulose crystallinity increased binding and digestibility. This study demonstrates that changes in biomass characteristics that improve cellobiohydrolase accessibility lead to improved cellulose conversion efficiency.

Biochemical Processing Integration Task Information Web-based information on the process integration project, including presentations made at recent review meetings, can be found at the following links (Process Integration Project Information, http://obpreview07.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 and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable.

1000 Independence Avenue, SW, Washington, DC 20585
by the National Renewable Energy Laboratory, a DOE national laboratory

DOE/GO-102008-2420 • January 2008
Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.