Quarterly Update

National Bioenergy Center Sugar Platform Integration Project

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

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The Sugar Platform Integration Project 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 "sugar 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 http://www.eere.energy.gov/biomass.html and information on Biofuels is posted at http://www.ott.doe.gov/biofuels/.

To discuss information in this update or for further information on the Sugar Platform Integration Project, contact Dan Schell at NREL, phone (303) 384-6869, email dan_schell@nrel.gov

NREL and USDA Collaborate to Survey Corn Stover Variability, Raleigh, NC, 10/22-24/03. Steve Thomas (NREL) traveled to Raleigh, NC to collect corn stover from 25 genetically diverse inbred lines of corn for evaluation. This work is being done in collaboration with Dr. Sherry Flint-Garcia (USDA/ARS, Raleigh, NC) and Dr. Ed Buckler (USDA/ARS; recently relocated to Cornell University). Dr. Buckler is a co-principle investigator on a NSF Plant Genome Initiative grant to study genetic diversity among maize cultivars. See the following links for additional information: https://www.fastlane.nsf.gov/servlet/showaward?award=9872631 and https://www.fastlane.nsf.gov/servlet/showaward?award=0321467). Similar samples from the same 25 inbred lines will also be obtained from a field managed by Dr. Bill Tracy at the University of Wisconsin, Madison.

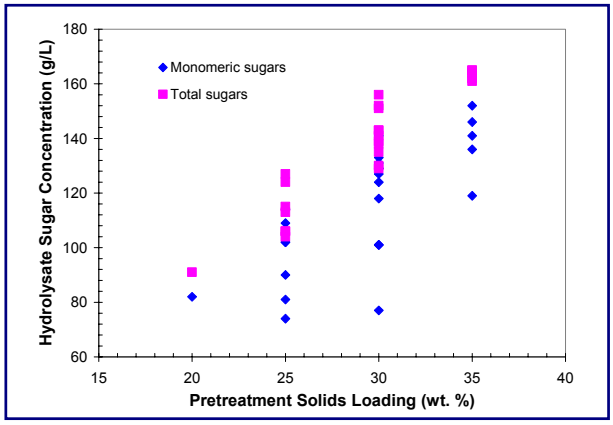
USDA ARS Researchers meet with NREL, 11/3/03. As a sidelight to the ASA-CSSA-SSSA meeting, Steve Thomas (NREL) organized a meeting between seven ARS researchers led by Ken Vogel (ARS, Lincoln, NE) and a dozen NREL NBC staff members. The ARS researchers were particularly keen to discuss the Sugar Platform process design as a prelude to deciding what goals ARS should pursue in the areas of crop breeding, production and harvesting to support the USDA's role in the Bioenergy Initiative. Thermochemical processing approaches to biomass conversion were briefly introduced during roundtable discussions. This meeting resulted in a clearer understanding on both sides about our respective roles in Bioenergy research and development. Surprisingly, while the USDA/ARS Bioenergy Program is investigating many crop species as potential biomass crops, no resources are currently being devoted to examining corn/corn stover because of perceptions within the ARS that corn stover is not sustainable as a biomass feedstock.

R&D Progress

High Solids Pretreatment. Researchers continue to make good progress in demonstrating and characterizing dilute sulfuric acid pretreatment performance at very high solids loadings, which economic analysis indicates is a key to cost effective operation. The first systematic investigation on the effect of solids loading on pretreatment performance using corn stover as a model lignocellulose feedstock has been completed. Performance was investigated by conducting a response surface experimental design in which xylose yields and enzymatic cellulose digestibilities were used as measures of pretreatment efficacy.

The most promising result was to demonstrate, at the 30% solids level, an overall conversion (i.e., by the combination of dilute acid pretreatment and subsequent enzymatic cellulose hydrolysis) of 90% of the cellulose and xylan in the corn stover to monomeric and oligomeric sugars. However, we believe this value may be slightly high because some sucrose in the raw corn stover (see the next research highlight) appears to survive pretreatment as glucose, thus biasing the result. Work is underway to resolve this issue. The result is still extremely promising and suggests we are close to achieving the Biomass Program's technical targets for pretreatment specified in the 2002 design case, (2002 Basecase Design Report) which is a prerequisite to realizing a cost-effective process. Other significant findings were that higher xylose yields are achieved at lower solid loadings (25%) whereas higher cellulose digestibilities are achieved at higher solid loadings (35%).

Results from these recently completed pretreatment experiments are presented in the plot below showing sugar concentration (sum of all five biomass sugars: glucose, xylose, arabinose, galactose, and mannose) in the hydrolysate liquor as a function of pretreatment solids loading. The wide range in values at a fixed solids loading is due to differences in pretreatment severity across the experimental design space. The results demonstrate that high hemicellulosic sugar concentrations can be produced in hydrolysate liquors.



A series of additional corn stover pretreatment experiments was completed that added information to the results presented above in order to better characterize and mathematically model the kinetics of high-solids dilute sulfuric acid pretreatment. This work provided additional baseline performance information on hemicellulose hydrolysis yields and enzymatic cellulose digestibilities achieved using high-solids processing conditions. Incorporating the data generated in these experiments increases the reliability of regressed model parameters and improves the kinetic model's predictive ability. Compositional analysis of hydrolysate liquors and solids is currently underway and enzymatic digestibility of the pretreated solid will be tested in January.

Corn Stover Composition and Pretreatment. Recent results suggest that a large fraction of the sucrose present in corn stover can survive dilute sulfuric acid pretreatment, which implies that a larger amount of corn stover carbohydrates may be preserved during processing than was previously assumed. This discovery was made after performing a series of pretreatment experiments using whole-stalk harvested corn stover from northeastern Colorado that contained 5.6% sucrose by weight. Higher than expected sugar concentrations were measured in the hemicellulose hydrolysate liquors produced during these pretreatments (yield values are not yet available), indicating that our original assumption that all of the sucrose would rapidly degrade during pretreatment and thus not survive as a fermentable sugar was incorrect. This fortuitous finding occurred as a result of using for the first time a feedstock that contained high levels of sucrose; high sucrose levels are expected in stover harvested nearer to grain maturity and not exposed to large amounts of weathering and precipitation, i.e., conditions such as might be encountered during single-pass type harvest operations.

Biomass Rapid Analysis Method Development. Progress continues to be made in developing and demonstrating improved analytical tools for the emerging biomass conversion industry. We recently received a direct-light spectrometer for measuring raw feedstock composition and a mid-infrared range ATR probe which will be used with a FTIR spectrometer to measure the composition of material in (or exiting) pretreatment reactors. Both of these instruments will be installed in the Alternative Fuels User Facility's sugar platform pilot

plant over the next six months and tested for their ability to perform on-line measurements of raw and pretreated feedstock compositions. Ultimately, this type of instrumentation will be applied in both pilot- and commercial-scale plants to enable on-line process monitoring and control, which should greatly speed the pace of process development and technology deployment.

Related Activities

Cellulase Subcontracts. Since mid-2000, the Biomass Program has been working with the two largest global enzyme producers, Genencor International and Novozymes Biotech Incorporated. The objective of this collaboration is to develop low-cost enzymes for biomass conversion. For the latest information, links to press releases provided by the enzyme producers are given below.

Genencor Achieves Cost Reduction Target

Novozymes Achieves 2.3-fold Cost Reduction

Novozymes Begins Year Three Effort

Enzyme Sugar Platform Project Information. Web-based information on the ESP project including our recent presentations at stage gate review meetings can be found at the following link (ESP Project Information). A discussion of how stage gate management is used in the Biomass Program is also available at this site.

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