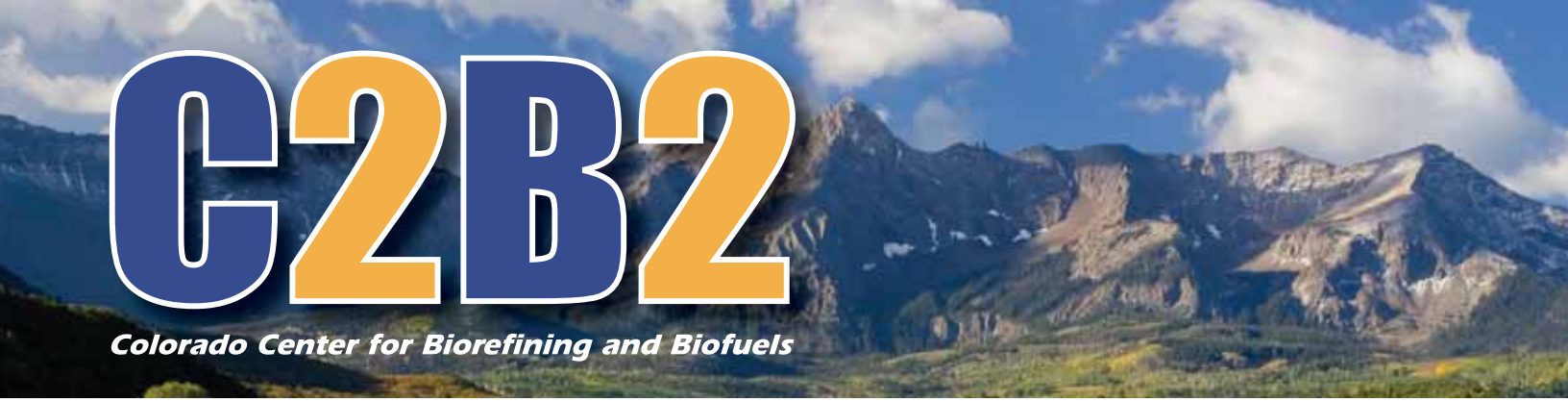

C2B2

Colorado Center for Biorefining and Biofuels

Spring 2009

Blowing the Lid Off Ethanol's Black Box

There are many obstacles blocking the path of ethanol to commercial mainstream, and production cost is among the most formidable. With numerous facets of the production process still technological works in progress and a variety of variables to consider in optimizing each small step of the process, a pathway for producing ethanol at a commercially viable quantity, quality and price is proving elusive. But researchers, such as Min Zhang at the National Renewable Energy Laboratory (NREL) National Bioenergy Center in Golden, are aiming to change that by confronting some of the most fundamental supply-side technological problems of ethanol production.

These days, Zhang and fellow NREL scientists, as well as others within C2B2, are focusing on upstream issues related to the pretreatment and fermentation processes by which cellulosic ethanol is produced from biomass. In particular, Zhang and her NREL colleagues are examining the toxic components of pretreated biomass hydrolysates that hinder the production of ethanol via fermentation. While the toxicity issue may seem esoteric and narrow in scope, Zhang says the work they are conducting in that area may have broad ramifications on the future economic competitiveness of not just ethanol but all biofuels produced by biochemical conversion of lignocellulosic feedstocks.

"It's a very difficult, complex set of issues to resolve," says Zhang. "In the past, it's been kind of a black box, where we knew fermentation didn't work but we didn't really know why it didn't work. Now we are digging deeper than others have to understand the toxicity issue. A better understanding of toxicity should provide guidance for pretreatment processes [associated with producing ethanol and other fuels from biomass] and it can have a significant impact on how we approach the fermentation process as well. What we learn here, we hope can apply to other biomass materials."

The crux of her current work with hydrolysates is finding an economical way to overcome the toxicity problem in the pretreatment and fermentation processes. To reduce the cost of cellulosic ethanol production, the seemingly logical first step is to increase the biomass load with minimal conditioning. But the trade-off with that approach, Zhang points out, is that it tends to produce higher levels of hydrolysate toxicity. While current processes are effective at pretreating biomass to create suitable substrates for conversion to biofuels, they also yield toxic compounds that inhibit the growth and ethanol productivity of fermentation organisms, including yeast and bacteria, thus curbing production of the sugars from which ethanol is derived.

Current methods for reducing toxicity in hydrolysates are somewhat effective, says Zhang, but the cost associated with the detoxification is still high and it reduces sugar yield in some cases. "The sugars we want," she says. "The other things, like toxic compounds, we don't want."

There are two main paths to addressing the issue of toxicity hindering production of cellulosic ethanol, according to Zhang. "We can try to reduce toxicity from a pretreatment perspective or we can try to engineer organisms that [during the fermentation process] can withstand those toxic compounds."

Before committing to follow one path or the other (or both), researchers are focusing on learning more about the toxic compounds created during pretreatment processes that inhibit organisms used in fermentation, among them carboxylic acids (primarily acetic acid), sugar degradation products such as furfural and hydroxymethylfurfural (HMF), phenolics from lignin degradation and inorganic salts in the case of diluted acid pretreament. In an article they co-authored in 2008, Zhang and colleague Philip T. Pienkos explain that "reducing the cost of cellulosic ethanol production will likely require enhanced understanding of the source and mode of action of hydrolysate toxic compounds, the means by which some organisms resist the actions of these compounds, and the methodology and mechanisms for conditioning hydrolysate to reduce toxicity."

To gain a better understanding of the toxicity problem that hampers the conversion of cellulosic biomass to sugars, Zhang is leading an effort at NREL to profile a wide range of toxic compounds produced during pretreatment, then to catalog those profiles in a comprehensive "master" database. What makes that profiling work so complex — and sometimes tedious, Zhang acknowledges — is the huge array of biomass feedstocks, pretreatment and conditioning methods, fermentation methods and fermentation strains that must be considered. As she and Pienkos note in their 2008 article, "Different biomass feedstocks and pretreatment processes generate different combinations of toxic compounds; different fermentation strains have different levels of natural resistance; and changes in the fermentation processes can lead to different levels of resistance."

Still, their work continues in earnest. Once a set of standard

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Student / Researcher Spotlights

Bryan Woodruff is a second year Ph.D. candidate in the chemical and biological engineering department at the University of Colorado at Boulder. Funded in part by a C2B2 Seed Grant, Bryan is researching the effects of operating conditions and reactor design on the conversion efficiency and product distribution of biomass gasification at high temperatures. After completing his doctorate, Bryan plans to continue working in the field of renewable fuel production.

Bettina Broeckling is a postdoctorate fellow at Colorado State University (CSU). She has a B.S. in Biology and a Ph.D. in Cell and Molecular Biology from Virginia Tech. Bettina's research at CSU, funded by a C2B2 Seed Grant, is focused on manipulating sucrose transport in sugar beets in order to achieve greater rates of photosynthesis and plant biomass.

Whitney Jablonski is in her first year of Ph.D. studies in Chemical Engineering at Colorado School of Mines and works at the National Renewable Energy Laboratory on steam reforming catalysis projects. She graduated from Northeastern University with a B.S. in Chemical Engineering. Her research focus is looking at the reforming ability of solid oxide fuel cell anodes using a feedstock that stimulates biomass gasification process gas.

Rakhi Patel is a second year Ph.D. candidate in the chemical engineering department at Colorado School of Mines. She is currently working with environmentally benign nano-composites and PolyLactic Acid (PLA) composites suitable for high temperature applications. Her focus is on blends that can be regarded as a new class of ecologically responsible and economically viable bio-based materials.

Mary-Kate O'Brien is in her senior year as a Chemical Engineering student at the University of Colorado at Boulder. Her research is focused on renewable biofuels stemming from bacteria emissions. Upon graduating from CU, Marykate would like to begin working in the renewable energy field as well as continue with her studies in order to seek advanced degrees.

C2B2 Director Attends Historic Bill Signing

Professor John Dorgan, Colorado School of Mines Site Director, attended the signing of the American Recovery and Reinvestment Act by President Barack Obama on Tuesday, February 17th at the Denver Museum of Nature and Science.

"I'm grateful to Congressman Perlmutter for the invitation and for his unwavering support of renewable energy development in Colorado" says Dorgan. Joining Professor Dorgan at the signing was David Hiller, Executive Director of the Colorado Renewable Energy Collaboratory which provides matching dollars from the State of Colorado to C2B2.

President Obama's remarks were preceded by Colorado Governor Bill Ritter speaking about Colorado's role in the New Energy Economy. Dorgan noted that Governor Ritter emphasized the importance of creating new jobs and making Colorado universities research leaders in renewable and alternative energy.

There is no doubt that Colorado has a dominant role to play in renewable and alternative energy production according to Dorgan. He cites C2B2 expertise in feedstock engineering, biotechnology, and thermochemical conversions as areas where C2B2 participants are shaping the future of the global energy industry.

"The President's decision to sign this bill in Colorado is completely appropriate. C2B2 and our collaborating sponsors are on the vanguard of producing sustainable energy systems that will create jobs, facilitate national security, and protect the environment," concludes Dorgan.

Colorado Center for Biorefining and Biofuels

Colorado Renewable Energy Collaboratory
Partners for Clean Energy

Professional Short Course

May 11–13, 2009
Fort Collins, Colorado

The C2B2 Professional Short Course has been developed to provide a comprehensive environment for the educational growth, training and professional development of industry and research professionals in biorefining and biofuel fields.

Registration

Registration includes meals, networking receptions, workshop materials.

Members: $1,000
Deadline 4/1/09

Non-Members: $1,500
Deadline 4/24/09

To Register:
Contact Frannie Ray-Earle
Center Coordinator
C2B2@colorado.edu
Ph. 303.492.7736

Short Course workshops will span the breadth of renewable bioenergy research and innovation via C2B2's six research thrusts:

- Feedstock Engineering, Plant Biotechnology & Crop Science
- Biochemical Engineering & Bioconversion Technology
- Thermochemical Engineering & Thermoconversion Technology
- Process Engineering: Biomass Hydrolysis, Fluid Dynamics & Separations
- Product Engineering: Bioproduct Synthesis & Biofuels Characterization
- Life Cycle Assessment & Policy Analysis

www.C2B2web.org

Colorado Renewable Energy Collaboratory
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C2B2 is a cooperative research and educational center devoted to the conversion of biomass to fuels and other products, supported by state, institutional, and industry funds. The mission of C2B2 is to become the world's leading center in biorefining and biofuels research and education.

We provide private industry with one-stop access to researchers, laboratories, students, and educators from four innovative institutions, each having unique strengths in biofuel and biorefining application areas.

Colorado Renewable Energy Collaboratory
Created to develop energy technologies for rapid commercialization, the Collaboratory consists of the following institutions:

University of Colorado at Boulder
Ranked in the top 25 nationally in Chemical and Biological Engineering, Molecular and Cellular Biology, and Biochemistry.

Colorado State University
Ranked in the top 10 nationally in Agricultural Sciences with an internationally renowned Engines and Energy Conversion Laboratory.

Colorado School of Mines
One of the few universities uniquely focused on energy research.

National Renewable Energy Laboratory
The only national laboratory dedicated to renewable energy and energy efficiency research and development (R&D).

(ETHANOL'S BLACK BOX continued from page 1)

methods have been established and a master database compiled, researchers then can gauge how different types of microorganisms used in fermentation are impacted by individual toxic compounds. With a stronger understanding of those toxic compounds and their effect on the microorganisms used in fermentation, scientists will be better informed as they decide whether it is more cost-effective to address the problem by attempting to curb formation of toxic compounds or by attempting to engineer more resistant microorganisms.

At that point, they will be a step closer to helping lignocellulosic materials such as agriculture residues, woody biomass and herbaceous plants fulfill the potential that so many see as renewable feedstocks for ethanol fuel production. Likewise, the U.S. will be a step closer to fulfilling a Department of Energy goal that biofuels account for 30 percent of American transportation fuel usage by 2030.

Stay tuned, says Zhang, because her research team has already arrived at some significant findings. Those findings will be disclosed in a paper she will deliver this May at the Society for Industrial Microbiology's 31st Symposium on Biotechnology for Fuels in San Francisco.

C2B2's Semi-Annual Meeting

Boulder, Colorado — February 5-6, 2009

C2B2 researchers, faculty, and students came together with sponsor members in Boulder, CO this February for our spring Semi-Annual Meeting. As a venue where academia and industry converge, the meeting afforded researchers an occasion to showcase their work while providing all attendees with a beneficial networking opportunity. The meeting's guest speaker was Melissa Klembara of the Department of Energy, who gave an informative talk about the Biomass and Integrated Biorefinery Programs. The Fall Semi-Annual Meeting will be held September 21-22 in Fort Collins.