New processing steps promise more economical ethanol production

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Why isn't ethanol production growing by leaps and bounds in the face of higher gasoline prices? Ethanol production from cornstarch is a $10 billion dollar business in the United States and 4 billion gallons of ethanol will be produced in 2006. In his 2006 State of the Union address, President Bush called for doubling ethanol production by 2012, and replacing 75 percent of Middle Eastern oil with bioethanol from renewable materials by 2025.

"We have the technical ability, but making ethanol production economical is the problem," said Y.H. Percival Zhang, assistant professor of biological systems engineering in the College of Agriculture and Life Sciences at Virginia Tech.

Zhang has developed a more cost effective pretreatment process that he will report on at the 231st American Chemical Society National Meeting in Atlanta March 26-30.

Ethanol now comes from corn kernels. "But that is food," Zhang said. "If we want to produce 30 to 60 billion gallons of ethanol, which is what is needed to meet the President's goal, we have to use the entire plant, or the stover (leaves, stalks, and cobs), and leave the kernels as food." The largest challenge for bioconversion from raw materials to bioethanol is high processing costs, resulting in higher prices for bioethanol than for gasoline.

Corn stover is the most abundant agricultural residue in the United

States. The challenge is separating the sugars from the lignocellulose -- the combination of lignin, hemicellulose, and cellulose that form plant cell walls. Many technologies have been developed to convert lignocellulose to sugars, but the costs are still high and sugar yields are low. "No one wants to take the risk -- to invest $1 billion in a large-size biorefinery based on lignocellulose," said Zhang. "Processing costs are also high. It requires chemicals, utilities, enzymes, and recycling in the pretreatment and the sequential processing stages."

Zhang's cost-effective pretreatment process that integrates three technologies – cellulose solvent pretreatment, concentrated acid saccharification, and organosolv, and overcomes the limitations of existing processes. Instead of a high pressure system that operates at between 150 and 250 degrees C, Zhang's "modest reaction" operates at atmospheric pressure and 50 C (120 F) to pretreat corn residue to free the solid polymeric sugars. In a several-step pretreatment system, Zhang uses a strong cellulose solvent instead of highly corrosive chemicals, high pressure, and high temperature to breakup the linkages among lignin, hemicellulose, and cellulose.

During Zhang's gentler process, there is no sugar degradation and inhibitor formation. In the following step, he creatively uses a highly volatile organic solvent to precipitate dissolved cellulose, extract lignin, and enable effective chemical recycling. After pretreatment and reagent recycling, lignocellulose can be fractionated into four products: lignin, hemicelluose sugars, amorphous cellulose, and acetic acid. "Co-products can generate more income, making biorefinery more profitable, and enable satellite biorefineries that fully utilize scattered lignocellulose resources," said Zhang. "For instance, lignin has many industrial uses, from glue to polymer substitutes and carbon fiber; and xylose can be converted to a healthy sweetening additive – xylitol, or to the precursors for nylon 6."

Amorphous cellulose, which is converted from crystalline cellulose, is another advantageous product from Zhang's process because in this form the cellulose material is more accessible for further hydrolysis, resulting in a higher sugar yield, higher hydrolysis rate, and less enzyme use. Zhang tested amorphous cellulose hydrolysis by adding special enzymes (Trichoderma cellulases) from Genencor International. The result is that about 97 percent of the cellulose is digested after 24 hours of the hydrolysis process.

Zhang, who has been at Virginia Tech since August 2005, began his research at Dartmouth Thayer School of Engineering, where he received his Ph.D., was a postdoctoral research associate, and then a research scientist. He and Lynd have applied for a U.S. patent for this pretreatment, which has been licensed to the bioethanol start-up company, Mascoma Co. After joining Virginia Tech, Zhang made another significant improvement based on the previous patent, and Virginia Tech has filed for a global patent.

Zhang is collaborating with the National Renewable Energy Laboratory and Oak Ridge National Laboratory, using NREL software to analyze the economic costs of various ethanol production strategies and ORNL facilities to test different enzymes and material performance. "NREL and ORNL have spent 30 years on lignocellulose processing, biocatalysis, and bioenergy research, and are glad to cooperate on new technologies which can effectively overcome the recalcitrance of lignocellulose," Zhang said. "We hope to soon establish the first pilot plant in Virginia based on this new technology with switchgrass."

Zhang will also present at the 28th Symposium on Biotechnology for Fuels and Chemicals in April.

Source: Virginia Tech