High-value chemicals produced from ethanol feedstocks could boost biorefinery economics

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The Southeast has abundant forest resources that could be used as feedstock for the biorefinery. Other locations would likely use different feedstocks. Image courtesy of Georgia Department of Economic Development

Biorefineries developed to produce ethanol from cellulose sources such as trees and fast-growing plants could get a significant economic boost from the sale of high-value chemicals – such as vanillin flavoring – that could be generated from the same feedstock. Revenue from these "side stream" chemicals could help make ethanol produced by biorefineries cost competitive with traditional fossil fuels.

At the 232nd national meeting of the American Chemical Society, a researcher from the Georgia Institute of Technology described green chemical processes that could produce chemicals worth up to $25 per pound from the same feedstock used to produce ethanol.

"It seems unlikely that fuel from a biorefinery – at least in the beginning – is going to be as cost-effective as fuel from traditional fossil sources," said Charles Eckert, a professor in the Georgia Tech School of Chemical and Biomolecular Engineering. "To make the biorefinery sustainable, we must therefore do everything we can to help the economics. If we can take a chemical stream worth only cents per pound and turn it into chemicals worth many dollars per pound, this could help make the biorefinery cost effective."

To help make that happen, Eckert and collaborators Charles Liotta, Arthur Ragauskas, Jason Hallett, Christopher Kitchens, Elizabeth Hill and Laura Draucker are exploring the use of three environmentally-friendly solvent and separation systems – gas-expanded liquids, supercritical fluids and near-critical water – to produce specialty chemicals, pharmaceutical precursors and flavorings from a small portion of the ethanol feedstock.

"These are novel feedstocks for chemical production," Eckert noted. "They are very different from what we've dealt with before. This gives us different challenges, and provides a rich area for interdisciplinary research."

Using near-critical water and gas-expanded liquids, Eckert and his colleagues have already demonstrated the production of vanillin, syringol and syringaldehyde from a paper mill black liquor side stream. They have also proposed a process that would generate levulinic acid, glucaric acid and other chemicals from the pre-pulping of wood chips. That process would use an alcohol-carbon dioxide mixture, followed by depolymerization and dehydration in near-critical water. Research aimed at producing high-value products from cellulose feedstocks is being done through the "AtlantIC Alliance," a coalition of three research institutions in the United States and the United Kingdom. The alliance, which includes Oak Ridge National Laboratory, Imperial College and Georgia Tech, seeks to solve the complex issues involved in economically producing ethanol fuel from cellulose materials such as wood chips, sawgrass, corn stovers – and even municipal waste.

"The feedstock would likely be different in different geographic locations, depending on what was readily available," Eckert noted. "In the Southeast, we have abundant forest resources. In the West, sources would include sawgrass, corn stovers and similar plant materials. In the United Kingdom, there is strong interest in producing fuels from municipal wastes."

The Alliance is taking a comprehensive approach to the biorefinery, conducting studies of how to maximize plant growth through genetic engineering, developing new microbial techniques for digesting cellulose, and applying environmentally-friendly chemical processes for reactions and separations. The organizers decided to pursue only non-food sources as their feedstock.

Using tunable solvent systems in the biorefinery would avoid the generation of wastes associated with processes that depend on strong acids – which must be neutralized at the end of the reaction.

For instance, near-critical water – familiar H_2O but at 250 to 300 degrees Celsius under pressure – separates into acid and base components that can be used to dissolve both organic and inorganic chemicals. When the pressure is removed, the water returns to its normal properties.

Gas-expanded liquids, such as carbon dioxide in methanol, provide a flexible solvent whose properties can be adjusted by changing the pressure. When the reaction is over, the pressure is released, allowing the carbon dioxide to separate from the methanol.

Supercritical fluids, such as carbon dioxide under high pressure, simplify separation processes. Separation of the carbon dioxide from chemicals dissolved in it requires only that the pressure be reduced, allowing the CO_2 to return to its gaseous state.

Though many challenges remain before biorefineries can be designed and built, Eckert says it is important to invest now in this renewable source of energy and chemicals.

"To make the biorefinery work will require a major effort that must be well coordinated among everybody working on it," he said. "The biorefinery is one of several answers that we need to pursue as part of a national energy strategy. Our future economic well-being requires us to deal with the energy issue."

Source: Georgia Institute of Technology

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