The evolution of ethanol: Promising new research goes beyond corn

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Fueling up your car with ethanol produced from blue-green algae may sound far-fetched. But Bill Gibbons, a professor and researcher in SDSU's Department of Biology and Microbiology, says it is close to reality – with commercial availability of this new generation of ethanol just four or five years away.

Gibbons and his colleagues at SDSU are among the nation's leaders in this innovative algae-to-biofuel concept, which aims to expand the ethanol resource in the U.S. and lessen reliance on foreign petroleum.

"Right now we are using 140 billion gallons of gasoline annually in the United States and spending $1 billion day to buy oil," Gibbons points out. "Think of the multiplier effect on our country if we could keep that money here," he adds.

Gibbons believes domestically produced biofuels are a key component for that turnaround, but he also knows that it can't all come from corn and soybeans. Presently the U.S. has the capability to produce over 13 billion gallons of "traditional" ethanol – which accounts for 10% of fuel used by American consumers. Revolutionary new research at SDSU focusing on cellulosic biomass and cyanobacteria – also known as blue-green algae – is providing alternatives to broaden the scope of ethanol production and use even further, Gibbons explains.

Cellulose & Cyanobacteria

SDSU researchers are accustomed to leading the charge on ethanol's development. It all began in the late 1970's when the first farm scale, fuel-ethanol production still in the nation was developed at SDSU.

Gibbons explains that the first generation of biofuels focused on using corn for ethanol and soybeans for biodiesel. "That was the traditional approach," he says.

The second generation of biofuels converts biomass or cellulosic material from grass, corn cobs and stover, trees or waste into ethanol. Researchers at SDSU have had a switchgrass breeding program for this type of bioenergy since the 1980s. A current five-year project at the North Central Sun Grant Center at SDSU has researchers working to optimize another native grass, prairie cordgrass, for ethanol production. This project is also developing biomass fractionation pretreatments, techniques to reuse enzymes, thermotolerant yeast, and a new generation of high solids bioreactors. Additionally, a Department of Defense project at SDSU is working to produce jet fuels from biomass such as prairie cordgrass.

Gibbons anticipates that biomass ethanol will be on the market by 2012. Sioux Falls-based POET, a leading producer of ethanol, has been producing cellulosic ethanol at a pilot plant near Scotland, S.D. since 2008 and is constructing its first commercial scale cellulosic ethanol plant at Emmetsburg, IA, which is scheduled to begin operating in 2012.

While ethanol produced from corn and cellulosic feedstocks offers a viable renewable energy alternative, it also comes with some limitations – primarily the fact that the majority of America's transportation fuel infrastructure (pipelines and distribution networks, storage facilities, and engines) have been designed for petroleum products, not ethanol.

Because of this, researchers at SDSU and around the country are pushing ahead to develop third generation biofuels that could be used as direct replacements for gasoline, diesel or jet fuel. “Because these third generation biofuels are similar or identical to their petroleum-derived counterparts, they are called direct ‘drop in’ replacements. They will seamlessly fit into the existing fuel transportation, storage, and utilization infrastructure,” explains Gibbons.

Research at SDSU to create these third generation biofuels is focusing on two approaches. One approach uses photosynthetic cyanobacteria – a bacterial version of algae – which can be reengineered to convert sunlight, carbon dioxide and water directly into third generation biofuels. “They are like little factories that spit out biofuel molecules without the need for starch or cellulose,” explains Gibbons.

A second process, called thermochemical pyrolysis, uses high temperatures and pressures to convert cellulosic biomass into long hydrocarbon chains that are similar to gas, diesel or jet fuel.

Gibbons acknowledges that the challenges with these third generation processes is obtaining high yields at fast rates, but the research is promising. He anticipates seeing these third generation fuels in pilot scale, pre-commercial testing by 2015.

Complimentary Systems

Gibbons sees all three generations of biofuels being utilized in the future. “Our new research is not intended to replace corn-based ethanol. We have the infrastructure for corn-ethanol plants in place, corn ethanol has benefits, and distillers’ grains are a valuable feed coproduct. So, those plants will remain,” he says, and anticipates that as corn yields continue to increase over the next decade there will likely also be similar continuous growth in corn ethanol production.

"The incentive with second and third generation biofuel research is to add to the portfolio and diversity of how liquid transportation fuels can be produced and where they can be used," he explains, noting that the military is increasingly interested in using renewable fuels.

As these new production processes emerge, Gibbons foresees ethanol production facilities with greenhouses constructed alongside, using engineered cyanobacteria to produce additional ethanol or drop-in biofuels from the unused carbon dioxide and low grade heat. "There are a lot of synergies between these systems to add value and efficiency to existing plants," says Gibbons.

The first round of cellulosic ethanol facilities are primarily being constructed as "bolt-ons" to existing corn ethanol biorefineries, to also take advantage of these synergies. Gibbons anticipates that as stand-alone cellulosic facilities are built in the future, they will likely be smaller plants (20 to 30 million gallons), and will be strategically located near the feedstock (grass, cornstover or timber) that they use. He explains this is because transporting these lower density feedstocks over long distances can be challenging and expensive. He adds that these new facilities could easily include secondary biofuel production via a facility for cyanobacteria as well.

Gibbons believes these formats will lead to a total biorefinery concept in the U.S. in the future. "Instead of producing one product, a cluster of facilities could produce ethanol, green gasoline or diesel, jet fuel, and industrial chemicals such as isoprene," he explains.

On that note, Gibbons believes the sky is the limit for where biofuel research and development is headed – and he says that spells opportunity for young people looking ahead to future careers. "The growth in biomass ethanol and third generation fuels is just beginning. We are going to need many more students in science and engineering to make this a reality. For individuals who want to stay in the Midwest and rural communities this is a great career field," Gibbons concludes.

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