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Sweet Ideas: Alternative Biofuels

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SWEET IDEAS
ALTERNATIVE BIOFUELS

Scientists and farmers alike promote research of alternative energy crops, but without necessary funds the search to find a cost-effective method continues.

BY LUCAS JAMESON

Ismail Dweikat, a sweet-sorghum researcher, is accustomed to going against the grain. He recalls a recent ethanol seminar where he opted to remove PowerPoint slides showcasing his sugary crop's environmental advantages over corn.

"I was the only sweet-sorghum guy in 2,700 people," he says with a wry smile. "I had to play it safe."

As he sits in his modest, cluttered office discussing ethanol, the smell of strong java fills the room. Nearby, a near-empty, coffee-stained pot sits atop a heater accompanied by a dozen mugs from research seminars around the country. The associate professor of agronomy and horticulture at the University of Nebraska-Lincoln gushes about the potential of his African plant, which from a distance looks like earless stalks of corn.

"You could put sweet sorghum up against anything — corn, switchgrass, stover, whatever — and nothing could beat sweet sorghum," he says.

But despite having numerous advantages over corn-based ethanol as an energy crop, sweet sorghum has been overlooked and its research under-funded, says Dweikat, a native of Palestine who has studied the crop for four years.

Other alternative feedstocks have suffered similar negligence. Advocates of these feedstocks say most of their crops require no irrigation, can be grown on marginal land, are less harmful to the environment and are more energy efficient than corn. Yet, these alternatives have long been overshadowed by the mature corn-based economy. The reason: Alternative biofuels are not yet economically viable.

One skeptic says that, in the long run, corn isn't an ideal energy crop.

"So we are going to want to see a transition to cleaner, greener versions … where there's a higher energy content in the fuel itself," said Daniel Kammen, professor of public policy at the University of California at Berkeley.

Those cellulosic feedstocks like sweet sorghum, switchgrass, forest residue and corn stover (the plant parts remaining after the grain is harvested) are getting some attention now. The Energy Independence and Security Act of 2007 requires cellulosic ethanol and other advanced biofuels to provide 21 billion gallons of fuel by 2022.

Ethanol made from cellulose is the same product as ethanol made from corn, but the production process is different. Instead of using enzymes to change cornstarch into sugars, the cellulosic process breaks down the cellulose of almost any biomass into sugars that can then be fermented into ethanol.

"Corn for ethanol is at least a good start," Dweikat said. "Now we've proved the concept works, so we need to move to a more productive source."

While making ethanol from alternative sources may become more efficient, several obstacles remain before ethanol made from kernels of corn takes a back seat.

According to several researchers, economists and farmers, alternative sources will require more federal and private funding, improvements in technology, a new infrastructure and support from farmers before any of those sources can supplant corn as the key ethanol feedstock.

"I look forward to the day when Texas ranchers can grow switchgrass on their country, and then have that switchgrass be converted to fuel," President George W. Bush said in a March 2008 speech at the Washington International Renewable Energy Conference.

For several years, the federal government has been touting switchgrass, a perennial prairie grass well-suited to Nebraska's climate. According to Rob Mitchell, a research agronomist for the U.S. Department of Agriculture, switchgrass as a biofuel crop "makes a lot of sense from many different angles." On paper, the advantages over corn seem overwhelming:

LAND: Switchgrass can be grown on marginal land, so farmers can save their best land for crops like corn and soybeans.

WATER: The deep, fibrous roots of the plant keep soil intact, prevent water runoff and improve water quality.

EQUIPMENT: Switchgrass is harvested just like hay, meaning many farmers don't need extra equipment to start growing it.

PESTICIDES: Once established, the crop needs very little pesticide or fertilizer and regenerates itself after harvest for 25 years or longer.

CONSERVATION: Switchgrass can be grown on Conservation Reserve Program land and creates a natural habitat for wildlife.

Mitchell, who helped complete a five-year study on switchgrass with several other UNL researchers, said that, of all the perennial prairie grasses, "switchgrass shows the most potential." Based on estimates, the study showed switchgrass produced 540 percent more energy than was needed to grow the crop and convert it to ethanol. The researchers also found that switchgrass fields produced about 300 gallons of ethanol per acre, or about 50 gallons less than an acre of corn will yield.

"One bale [of switchgrass] will make about 50 gallons of ethanol," Mitchell said.

And all of those bales could add up. An April 2005 study by the USDA and the U.S. Department of Energy predicted the United States could realistically produce about 1.3 billion tons of biomass for ethanol.

The National Renewable Energy Laboratory calculated that this biomass could replace more than half of the transportation fuel burned each year in the U.S., as reported in a 2007 article in National Geographic magazine.

With so much research put into unlocking the potential of perennial grasses, it is easy to put other crops on the back burner.

UNL sweet-sorghum researcher Dweikat is accustomed to such treatment.

"When the president said 'switchgrass,' the dam and the water broke and all the money came to switchgrass," he said.

Dweikat believes sweet sorghum is a better solution, calling it "an ideal crop for ethanol production."

Sweet sorghum is a drought-tolerant crop with tall, juicy stalks. The juice in the stalks is between 12 percent and 23 percent sugar. As an energy crop, sweet sorghum shares many benefits with switchgrass. Dweikat said sweet sorghum costs about $20 per acre to grow, about half the cost of corn. Sweet sorghum needs less water than corn and very little nitrogen to grow. And sweet sorghum is not a food crop.

"Growing sweet sorghum could release some of the pressure on corn and food prices," he said.

The juicy stalks are what make sweet sorghum unique. Dweikat said enough juice exists in one acre of the crop to produce between 400 and 800 gallons of ethanol, depending on the concentration of sugar. He believes he can eventually increase that number to 1,000 gallons per acre by combining different hybrids. The leftover stalks can then be collected and taken through the cellulosic process.

After four years of studying the crop, however, Dweikat hasn't received the funding to experiment on a large scale. Instead, he has relied mostly on his small plots on UNL's East Campus and watches with intrigue when area farmers dabble with the crop.

One such dabbler is Harold Witulski, a 77-year-old retired farmer. In 2007, Witulski planted one acre of sweet sorghum near his home, six miles southwest of Beatrice. Although he knew about the crop's potential as an energy crop, he planted it to make syrup.

"I was just kind of experimenting," he said. "I like to try new things."

After removing the heads and leaves of the sweet sorghum plants by hand, Witulski transformed his silage chopper into a silage squeezer, which squeezed the juice out of the stalks. He then cooked the juice into a molasses-like substance and used it to make cookies.

Although the majority went toward sweets, Witulski also made a little ethanol.

"All you have to do is get the right yeast, and you don't have to cook it," he said.

Dweikat hoped Witulski would plant another acre this year with one of his breeds of sweet sorghum.

"I might try a little bit of his new seed, but I'm getting old," Witulski said.

Dweikat acknowledges the potential of feedstocks like woody forest residue, corn stover and

FACTS FEEDSTOCK

- Switchgrass will yield nearly 540 percent as much energy as it takes to grow it. **– USDA agronomist Rob Mitchell**
- An April 2005 study predicted that the United States could produce 1.3 billion tons of feedstock for ethanol production. **– Departments of Agriculture and Energy**
- Sweet sorghum can yield 400-800 gallons of ethanol per acre. Corn yields about 350 gallons per acre. **– University of Nebraska–Lincoln agronomist Ismail Dweikat**
- Sweet sorghum needs between 12 and 15 inches of water per year to grow healthily. **– University of Nebraska–Lincoln agronomist Ismail Dweikat**
- Sweet sorghum costs about $20 per acre to grow, making raising it about half as expensive as corn. **– University of Nebraska–Lincoln agronomist Ismail Dweikat**
- The U.S. Department of Energy budgeted $726 million for renewable energy projects in 2007.
- The Energy Independence and Security Act of 2007 requires that the U.S. use 36 billion gallons of fuel from advanced biofuels, which includes cellulosic ethanol, by 2022.

CELLULOSIC

Cellulosic ethanol production is thought to hold the key to the future of ethanol in the United States. In December 2007, the Energy Independence and Security Act of 2007 allocated more than $4 billion over the next eight years for advanced biofuel research, development and production.

PHOTOGRAPH BY KOSUKE KOIWAI

Biomass from grasses, crop waste or woody materials is pretreated with either acid or gas to free cellulose from the lignin cell walls.

Gas-treated biomass is partially combusted, and the hydrogen and carbon monoxide exhausts are fermented into sugars and ethanol.

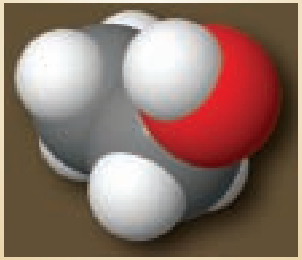
Released from the cell, the chemically complex cellulose is exposed to enzymes to "digest" it into simple sugars like glucose and pentose.

Micro-organisms convert the simple sugars to ethanol through a fermentation similar to wet and dry-mill ethanol production.

Distillation takes advantage of ethanol's lower boiling point to vaporize the fuel but not the water. The cooled ethanol vapor recondenses.

Left over lignin is a useful byproduct of cellulosic ethanol production. It can be burned to fire the still at the plant or used industrially.

The remaining water is removed from the distilled ethanol. A denaturant is added to make it undrinkable, then the fuel is ready to sell.



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GRAPHIC BY ALEX HAUTER

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garbage but questions their longevity.

"After a while, you're going to run out of wood," he said. "You need something that grows, and grows fast."

As far as Dweikat is concerned, it is only a matter of time before his sweet little crop becomes one of the main feedstocks for alternative ethanol.

Alternative feedstocks for ethanol production seem like a no-brainer. Perennial grasses and sweet sorghum are simple to grow, cheap and easy on the environment. Others, like wood chips and garbage, are just lying around in forests and landfills. But in the United States, not a single plant is producing commercial cellulosic ethanol on a massive scale. Nor is a single vehicle in the country running on cellulosic ethanol.

Most of the problem stems from the fact that cellulose is a difficult substance to break up. Scientists have been trying to find a cost-effective way to do so since the 1990s, but they aren't quite there yet.

"Some people are still underestimating how difficult it is going to be," Mark Emalfarb, president and chief executive of biotechnology company Dyadic, told The New York Times in April 2007.

Breaking down cellulose molecules requires the use of several expensive enzymes, which can cost up to five times more per gallon than the enzymes needed for corn-based ethanol.

Still, progress has been made. The U.S. Energy Department hopes to bring the overall cost of producing cellulosic ethanol to $1.07 per gallon by 2012. Production currently costs about twice that amount per gallon. To help the cause, the Energy Department designated $726 million for renewable energy projects in 2007 — in part, to help scientists and researchers reduce the processing cost of cellulosic ethanol.

One such scientist is Y.H. Percival Zhang, assistant professor of biological engineering at Virginia Tech University. Zhang has developed a new process that replaces the expensive high-pressure, high-temperature cooking process with a much cooler reaction that occurs at around 120 degrees Fahrenheit. Zhang said that once an ethanol plant is built to use his process, the production costs would be anywhere from $1 to $1.20 per gallon of cellulosic ethanol — a price competitive with corn ethanol. But such a plant is several years away, and Zhang said he doesn't think cellulose will compete with corn until 2015.

"We're still trying to get the money," he said. "It's a good process. We just need money and need time to build everything."

While scientists like Zhang have worked diligently to develop new processes to make cellulosic ethanol, others have stumbled upon possible solutions by chance.

PHOTOGRAPH BY KATE VEIK

"When the president said 'switchgrass,' the dam and the water broke and all the money came to switchgrass."

Ismail Dweikat

UNL sweet-sorghum researcher

For years, Susan Leschine, a microbiology professor at the University of Massachusetts, examined soil and sediment samples from around the world for the ideal plant-eating microbe. In the end, she discovered the type of microbe she was looking for just a short drive from her lab.

In the moist dirt of the Quabbin Reservoir, roughly 65 miles west of Boston, one of Leschine's lab assistants scooped up what she eventually dubbed the "Q" microbe. Leschine said she knew

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about three and a half years ago that she had something unique.

"We just decided to try adding higher concentrations of cellulose into cultures of the Q microbe; and not only did it digest it, it made ethanol as the only product," she said.

Reducing a two-step process into one is the key to the Q microbe's potential. And because the microbe occurs naturally, it saves time and money.

"The techniques for synthetic biology exist, but it's a pretty complex process, and it takes a lot of person hours to do that," Leschine said. "By luck, we found this microbe that already has those properties we were looking for."

Leschine is also the chief scientist of SunEthanol, a small company with an equity investment from VeraSun Energy. SunEthanol is now preparing to build a pilot plant in Missouri with the hope of riding the Q microbe to eventual commercial production.

"This first round is really tough," Leschine said. "The capital cost is huge."

Initial costs, infrastructure challenges and the difficulties of developing a market for a new crop are among the reasons that Ken Cassman, UNL professor of agronomy and horticulture, is skeptical about the feasibility of alternative ethanol feedstocks in the near future.

"At the same time, you have to do two things: Develop a new crop for a market, and a market for a new crop," he said.

But the ethanol industry is taking baby steps to reach mass commercial production of cellulosic ethanol. Test plants are popping up across the nation, including in Nebraska. Abengoa Bioenergy opened its test plant in York in October 2007, thanks in part to a $17-million grant from the U.S. Department of Energy. Abengoa will apply what it learns from the York plant, which makes ethanol from wheat straw, to a planned commercial-scale plant in Hugoton, Kan. The test plant in York is a 1/100th scale plant. The Energy Department has provided Abengoa with an additional $76-million grant to help build the Kansas plant.

Private investors are also starting to jump on board. In January 2008, The New York Times reported that General Motors bought a stake in Coskata, a start-up company from Warrenville, Ill. Coskata plans to make ethanol from feedstocks other than corn.

According to researchers, private investments like these are important to ensure the future of cellulosic ethanol. But suppose everything for the industry goes smoothly and ethanol from feedstocks other than corn takes off.

"Cellulosic ethanol will have to be regional," Leschine said.

"Using biomass and making liquid transportation fuels from it will definitely happen, but there's going to be lots of different ways it's going to work."

Cassman said he thinks the biggest challenge for cellulosic ethanol, once the process is profitable, will be infrastructure. Current ethanol plants would require modifications to switch to cellulosic feedstocks. Ethanol can't be transported through pipelines because of its tendency to pick up water. Also, storing the massive amounts of feedstock the government is asking for may prove difficult.

Part of the solution to many of these issues seems to be a regional ethanol system.

"I think that's exactly where it's going," said Mitchell, the switchgrass researcher.

In switchgrass's case, Mitchell said, the crop for a cellulosic plant must come from a 30-mile radius to make economic sense.

Zhang, the Virginia Tech bioengineer, echoed Mitchell's analysis.

"As more and more ethanol is produced from biomass rather than corn, you will need to promote the local economy," he said. "So you should use local resources for local ethanol."

Meanwhile, some ethanol supporters remain skeptical about a shift from corn.

"Farmers are never going to do this — they are never going to get rich doing this. There will never be enough money in it to convince people to do it," said Shawn Griner, a rancher in Iowa.

Others believe that improving corn yields could keep corn in the ethanol game for a long time. However, Cassman said he doesn't think yields will increase fast enough in the long run to keep up.

For farmers like Jeff Walmsley, the whole thing is pretty simple.

"It all comes down to the economics of it," said Walmsley, who farms near Norfolk. In the past, Walmsley has planted several grasses similar to sweet sorghum to use as silage for his cattle. Although he grows mostly corn and soybeans now, he said it was simple and cheap to grow the other crops.

Walmsley has converted several engines on his farm to run on ethanol, and he likes to do the same for other farmers. He said if a cellulosic plant opened near Norfolk and it was somewhat competitive with corn, he'd plant whatever crop was needed to support it.

According to Cassman, in 10 to 20 years, Walmsley may have more crop choices if he wants to support ethanol.

"I think corn ethanol eventually limits itself and maybe extinguishes itself altogether," Cassman said.

PHOTOGRAPH BY KATE VEIK

The Nine-Mile Prairie spans 230 acres, and is owned by the University of Nebraska Foundation. Located northwest of Lincoln, Neb., the prairie's name refers not to its size but that it is 5 miles west and 4 miles north of the University of Nebraska campus. About 350 plant species and more than 80 species of birds have been observed on the prairie.

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