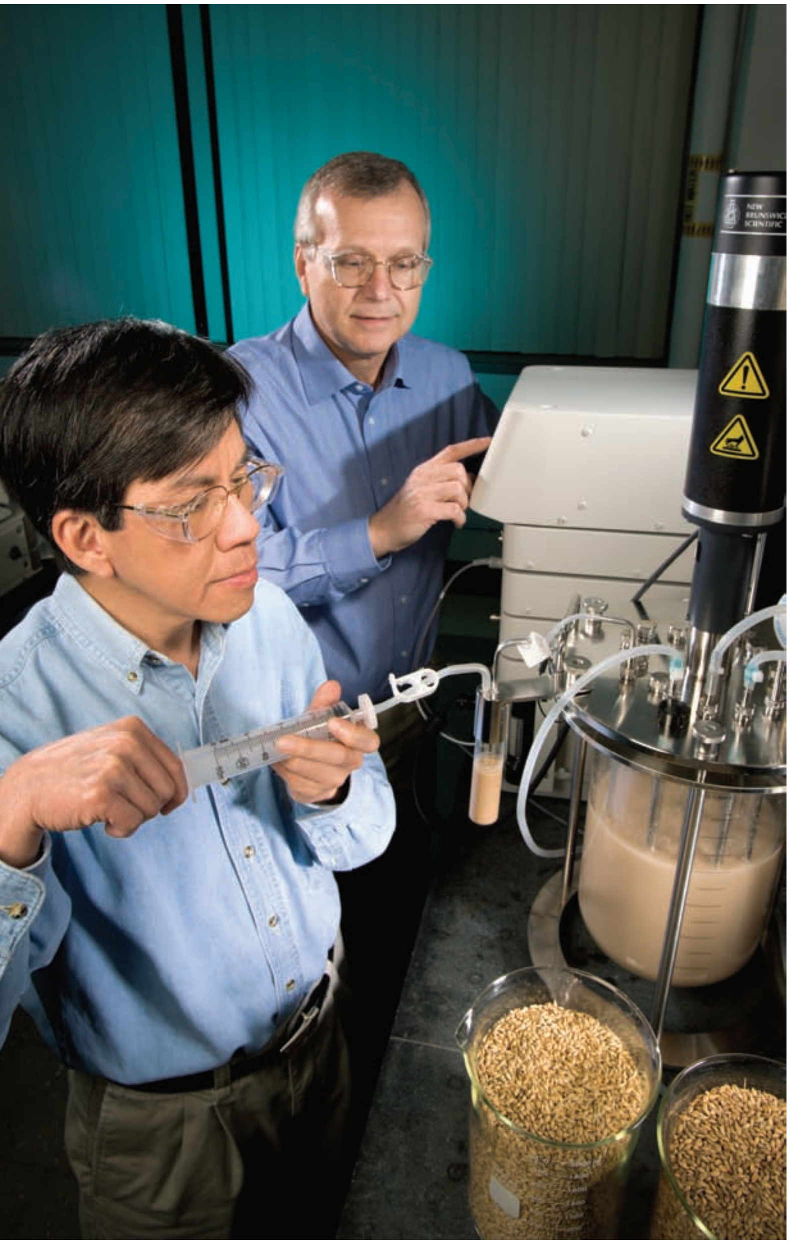
Fueling America—
Without Petroleum

PEGGY GREB (D768-1)



Chemical engineer John Nghiem (left) and research leader Kevin Hicks monitor a new process for converting barley into fuel ethanol.

The demand for alternatives to petroleum-based fuels is steadily rising.

Corn and soybeans—the dominant feedstocks for ethanol and biodiesel production in the United States—grow well in the central regions of the country. But are these the only available sources? What options exist for U.S. growers in other regions? How can corn and soybean feedstocks be improved?

Scientists at the Eastern Regional Research Center (ERRC) in Wyndmoor, Pennsylvania, are answering these and other questions about renewable fuels production. Their research focuses on four major areas: biodiesel, ethanol, thermochemical processes, and cost analysis.

"For years, ERRC has been a committed participant in alternative fuels research," says center director John Cherry. "This is a particularly exciting time, because so much of our research work is being adopted and used by industry."

Biodiesel: From Grease to Glycerol

What do animal fats, rendered materials, and restaurant grease have in common? Besides ready availability and limited marketability, they're all subjects of ERRC biodiesel research headed by research leader Bill Marmer. Scientists in his group have demonstrated that products of the rendering industry can be used as low-cost feedstocks for biodiesel production.

Biochemist Mike Haas and biologist Karen Scott are working with the Philadelphia Fry-o-Diesel company to demonstrate that trap grease—waste grease that restaurants and food companies collect from their drains—can be converted into a clean-burning, renewable fuel source.

Haas and Scott helped characterize trap-grease samples, advised the company on operation design, and analyzed the products of trial runs. They have successfully produced fatty acid methyl esters, the chemical compounds that make up biodiesel, from the grease. The esters are being tested to determine whether they meet accepted biodiesel standards.

These researchers are also developing a method to produce biodiesel directly from oil-bearing materials, including soybean flakes and rendered products. The oils or fats in the feedstock are treated with 18 percent methanol, forming biodiesel as the extractant. This would eliminate the need to isolate the oil before converting it to fuel, thereby reducing production costs, and would expand the amount of available fuel feedstocks.

Another objective of biodiesel research is to find uses for glycerol, a coproduct of biodiesel production.

"For every 100 pounds of biodiesel produced, you get 10 pounds of glycerol," says chemist Tom Foglia. "Current markets are saturated."

Concerned that increased biodiesel production could result in a hyperglutted glycerol market, ERRC researchers are investigating alternative uses for the compound. Molecular biologist Dan

Enzymes could improve the speed, efficiency, and cost of barley-based ethanol production.

Solaiman and microbiologist Rick Ashby have found that crude glycerol can be used to support microbial cell growth and production of polyester biopolymers, which can be used as plastics or adhesives, and biosurfactants, which are used in detergents or as antimicrobial agents. This is particularly important because crude glycerol is less marketable than pure glycerol.

In related studies, chemist Victor Wyatt demonstrated that glycerol could be used to produce a new class of prepolymers for making such products as coatings, resins, foams, and agents for remediation of polluted environments.

These alternative uses for glycerol have proved successful on a trial scale. Now the scientists are testing them at an industrial level through a cooperative research and development agreement with an international consumer products company.

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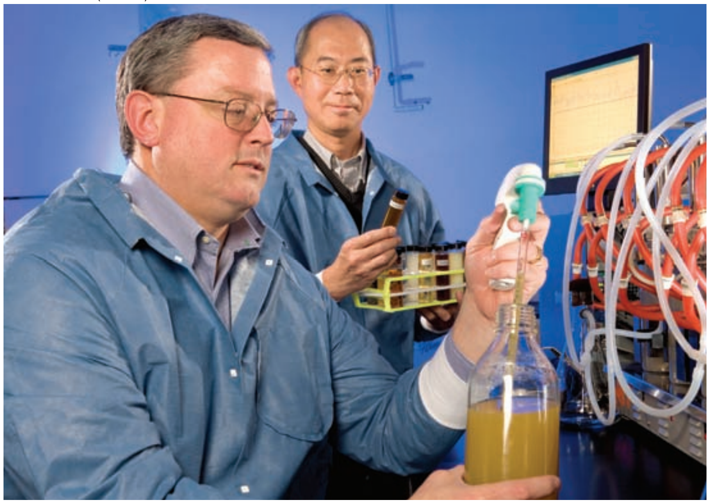

Microbiologist Rick Ashby (left) and molecular biologist Dan Solaiman monitor bacterial growth and production of a biopolymer for use in plastics and other products. The bacteria are growing in a nutrient broth containing glycerol, a coproduct of biodiesel production.

Ethanol: Beyond the Corn Belt

Affordable, available, and easy to work with, corn is the main feedstock for ethanol in the United States. As ethanol production increases—USDA chief economist Keith Collins estimates that our country could produce 12-13 billion gallons in 2009—so does the demand for suitable feedstocks.

To avoid overburdening the corn market, ethanol producers have two options: increase conversion efficiency or use an alternative crop. Several ERRC research projects have demonstrated how these can be done.

Food technologist David Johnston is investigating new processes using protease enzymes from microbial and fungal sources to produce ethanol more efficiently. In trials, Johnston found that adding enzymes during fermentation sped up the process and increased ethanol yields.

"The enzymes make more nutrients available for the yeast. They expedite the fermentation process and can also make it easier to separate liquid from solids after the ethanol has been removed," Johnston says. "This is important because the more efficiently you separate the free liquid from the solids, the more energy efficient the process can be."

Corn isn't the only available feedstock for ethanol. Research leader Kevin Hicks is collaborating with biotechnology company Genencor International; Virginia Tech, in Blacksburg, Virginia; and members of the barley industry to explore barley's potential as a feedstock in regions of the United States where corn is not the principal crop.

Hicks estimates that barley grown in North America could supply about 1 billion gallons of ethanol per year. The crop is well suited to the Mid-Atlantic, where it could be grown as a winter crop in rotation with soybeans and corn in 2-year cycles.

Currently, barley yields less ethanol than corn does, and the ethanol from barley is more expensive. Barley's physical properties—an abrasive hull and low starch content—impede production efficiency. But Hicks and his colleagues are overcoming these hurdles with research.

With Genencor, the researchers are developing new enzyme technology that could improve the speed, efficiency, and cost of barley-based ethanol production.

They also collaborated with Virginia Tech researchers to develop barley varieties with higher starch content and a loose hull that generally falls off during harvest or grain cleaning. Initial studies suggest that such varieties have promise as a feedstock.

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Biologist Karen Scott prepares a sample of trap grease for conversion to biodiesel. In the foreground are samples of distilled (left) and crude (center) biodiesel from trap grease.

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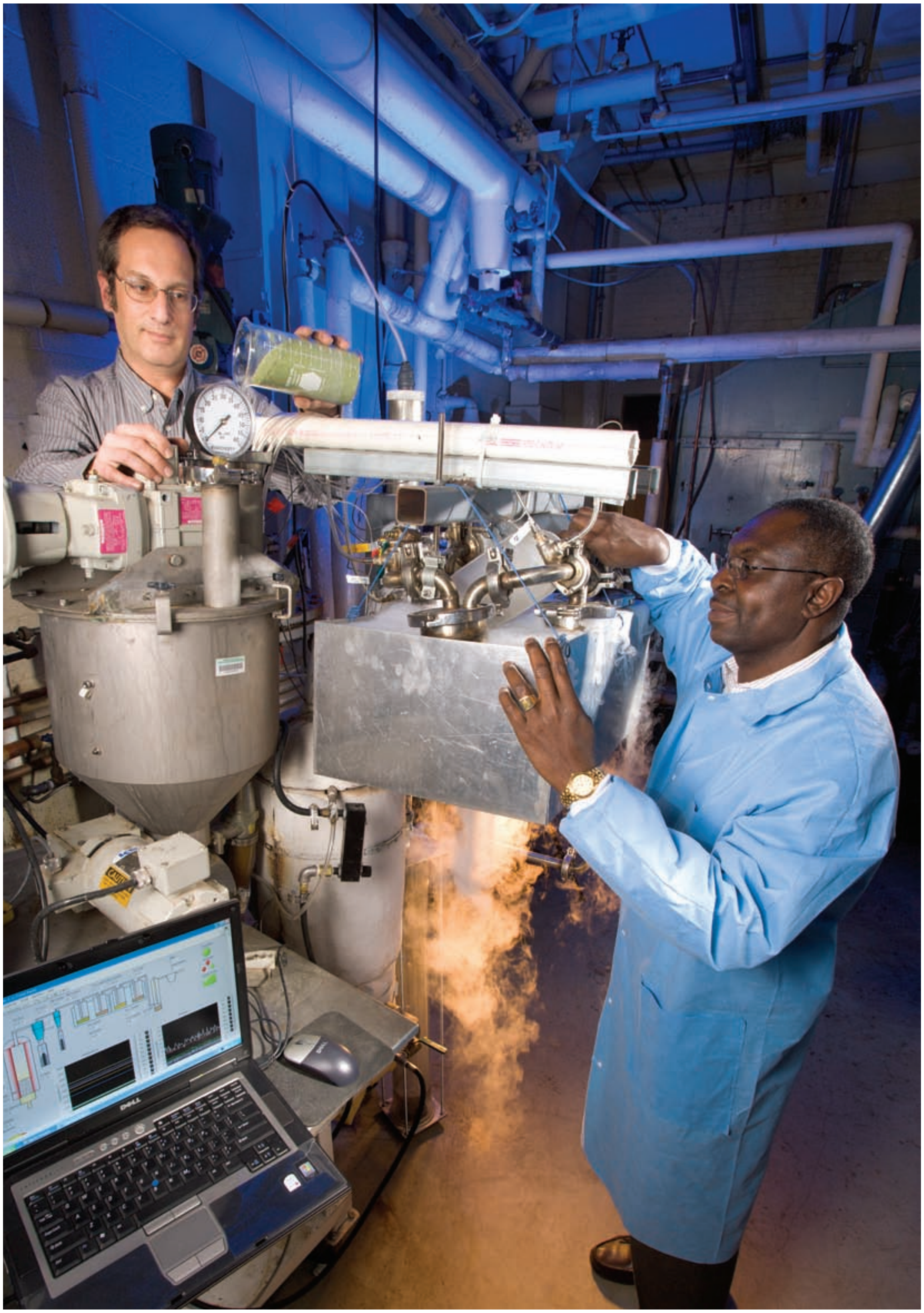

Engineers Neil Goldberg (left) and Akwasi Boateng operate a fluidized-bed thermochemical reactor they designed and built for converting crop residues into renewable bio-oils and hydrogen fuels.

Biomass—materials such as sawmill waste, straw, and cornstalks—is heated in a reactor and converted into liquid (bio-oil) and synthetic gas.

In one study, for example, a hull-less barley produced 2.27 gallons of ethanol per bushel, whereas hulled barley produced 1.64 gallons per bushel.

The scientists are now studying which conditions will promote the most cost-effective production of barley-based ethanol.

Breaking Down the Biomass

There are two main processes, or "platforms," for making fuels from biomass: sugar and thermochemical conversion. The sugar platform involves breaking down complex carbohydrates in the biomass—materials such as sawmill waste, straw, and cornstalks (stover). Then, yeasts metabolize, or consume, the simple sugars to make alcohol.

Breaking down those complex carbohydrates requires a lot of energy, Hicks says, and special microorganisms are required to convert some sugars into ethanol. And, ironically, the process creates a lot of carbon dioxide—the greenhouse gas that's helping to spur the biofuels movement.

The thermochemical platform involves heating the biomass in a reactor and converting it into liquid (bio-oil) and synthetic gas (gaseous fuels comprising carbon monoxide, hydrogen, and low-molecular-weight hydrocarbon gases such as methane and ethane). Chemical engineer Akwasi Boateng has led much of the ERRC research on this process.

In a study with research leader Gary Banowetz and colleagues in Corvallis, Oregon, Boateng converted grass seed straw into synthetic gas using small-scale gasification reactors. Built to serve a farm or small community, these reactors could provide an environmentally friendly and economic use for the 7 million tons of straw produced by the grass seed industry every year in the Pacific Northwest.

Neither the sugar platform nor the thermochemical platform has been perfected yet, Hicks cautions.

"Each one has technical and economic hurdles that must be solved through research," he says. "We're trying to compare the processes and determine which, if perfected, would give the most useful energy from a given amount of biomass. We're working with international experts to make intelligent decisions on where to focus our efforts."

A Model Approach: Cost Analysis

Price is one of the major factors inhibiting the spread of biofuels. Reducing production costs would make them more competitive with petroleum-based fuels—but where can scientists cut costs?

Engineers Winnie Yee and Andy McAloon create technical models to guide research efforts toward economically feasible processes. With the models, they analyze every aspect of a biofuel production process and determine where cost-cutting would be most effective. This allows researchers to pinpoint the exact steps in the process that need to be modified.

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Engineers Andrew McAloon (left) and Winnie Yee (right) explain the economic advantages of a new fuel ethanol process to ERRC director John Cherry.

"It's important to know that our research makes economic sense, that these processes will be competitive enough for industry to accept them," McAloon says.

Haas used one of McAloon's models to analyze his efforts to create biodiesel from soy flakes. The model estimated that by first drying out the moist flakes, Haas could reduce the amount of methanol required later, thereby reducing the cost per gallon from $2.83 to $2.66. Haas and his colleagues are currently working to reduce that cost even further to a point of commercial competitiveness.

For about 10 years, ERRC has been providing these technical models for ARS scientists. Developing a model from the ground up is time-consuming, McAloon says, but once developed it can be modified to meet the needs of a specific product or process. Within the past year alone, he estimates, ERRC has produced several hundred copies of their models for researchers within ARS and around the world.

"Our scientists are approaching biofuels research from many different angles that allow us to come up with comprehensive solutions," Cherry says. "We've made some great discoveries here at ERRC that have helped improve biofuel production, and I'm confident that we'll see even more improvements in the future."—By **Laura McGinnis,** ARS.

This research is part of Bioenergy and Energy Alternatives, an ARS National Program (#307) described on the World Wide Web at www.nps.ars.usda.gov.

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