

# New Milling Methods Improve Corn Ethanol Production

A golden kernel of corn is a rich source of many food and industrial products, one of which is ethanol. Ethanol production in the United States grew from 175 million gallons in 1980 to a record 2.8 billion gallons in 2003. This boost in ethanol demand has created a significant new market for corn.

"The United States is producing more ethanol from corn and other domestic, renewable resources than ever before," says Kevin Hicks, research leader in ARS's Crop Conversion Science and Engineering Research Unit. "Almost 10 percent of the U.S. corn crop is used to make fuel ethanol. That's good for

America's farmers. Ethanol is also good for the environment because its use reduces greenhouse gas emissions."

Hicks and colleagues at the ARS Eastern Regional Research Center (ERRC), in Wyndmoor, Pennsylvania, are developing new ways to reduce the costs of producing this important fuel and other corn products. They're also creating computer models to help researchers and ethanol producers estimate how different techniques might affect the bottom line.

## Alternative Dry-Grind Techniques

The dry-grind process is the most common method used to produce fuel ethanol. In it, the whole corn kernel is ground and converted into ethanol. This method is relatively cost effective and requires less equipment than wet milling, which separates the fiber, germ (oil), and protein from the starch before it's fermented into ethanol. But the cost of making fuel ethanol must be lowered even further before ethanol can compete favorably with gasoline.

To further lower costs for the dry-grind process, Frank Taylor, a chemical engineer at ERRC, and Vijay Singh, a professor from the University of Illinois at Urbana-Champaign, developed and patented a process that permits low-cost recovery of nonfermentable corn components, such as germ and fiber. These can be sold as valuable co-products for food or feeds. The process treats corn kernels with anhydrous ammonia gas to loosen up the kernel components so they can be easily separated and recovered.

Taylor and colleagues also developed another modified dry-grind process called continuous fermentation with ethanol stripping. It allows more efficient production of ethanol in smaller, less expensive fermentors. (See "Bioenergy Today," *Agricultural Research*, April 2002, p. 4.)

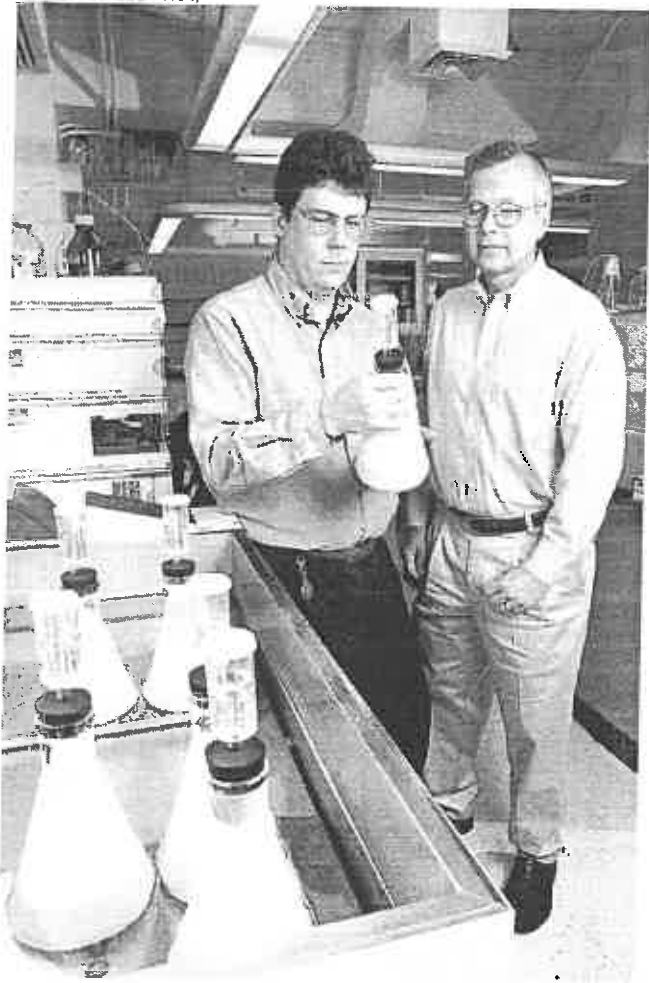
## Wet Milling Made Easier

In the wet milling process, corn is separated into its four basic components: starch, germ, fiber, and protein, which are each made into different products. The advantage of wet milling is that, besides ethanol, valuable co-products such as corn oil are also produced. The disadvantages are that the equipment is expensive and the process uses hazardous sulfur dioxide.

During conventional wet milling, corn is steeped for 24 to 36 hours in water and sulfur dioxide to begin the separation of the starch and protein connections. Then the corn is coarsely ground to break the germ loose from other kernel components. Later, the starch is separated out and converted into sweeteners or ethanol.

ERRC food technologist David B. Johnston and Singh developed a faster, cheaper way to break down the starch and protein connections. They are using several commercially avail-

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Food technologist David Johnston (left) and research leader Kevin Hicks check fermentability of enzymatically milled corn.

able protease enzymes to do the job. This process requires much less sulfur dioxide during the steeping stage of wet milling.

The new method includes a 6-hour soaking in water of the corn kernels before milling. After about 3 hours of soaking, the enzymes are added. Then normal wet-milling steps are resumed.

Johnston says that in laboratory and pilot-scale trials, the enzyme method separated starch and proteins faster and yielded starch equal to or greater than the conventional process.

"With sulfur dioxide, there are regulations on emissions, and costlier equipment for processing is required," Johnston says. "Protease enzymes are also expensive, but we can lessen use of harmful materials in milling and produce the starch more quickly, using less energy."

### Predicting Costs

So, how might innovations like these affect the ethanol producer's bottom line? The Wyndmoor scientists recently completed several computer models to help answer that question.

Andy McAloon, head cost engineer of the Process and Cost Simulation Group, says the models estimate the cost per gallon to produce ethanol with various processes. The models, which run on Aspen Plus software, are based on data from commercial plants and current costs for equipment, materials, labor, supplies, grain, and utilities.

McAloon and chemical engineer Winnie Yee worked with researchers to create the models, which analyze how new methods affect ethanol production costs. They provide support to scientists and engineers to determine research directions and predict the costs of possible alternatives to standard industry practices.

"These models can save researchers and producers time and money by simulating the many variables involved in production instead of having to actually go through the complete process each time they want to adjust a system," McAloon says.

The scientists have just released what they believe is the first publicly available corn wet milling process and cost model. It was developed by McAloon, Yee, and food technologist David Johnston, with cooperation by the Corn Refiners Association. Johnston and co-workers plan to use it extensively in their work with protease enzymes.

Another model, made by Yee, McAloon, and Taylor, helps estimate costs for making ethanol by dry grind processes. For example, they showed that the ARS-developed continuous fermentation and stripping procedure could save 3 cents per gallon. Users can examine countless other possibilities—such as reclaiming wasted heat, converting some of the fiber to ethanol, or pulling out the germ before fermentation—to see how they would affect the cost of making a gallon of ethanol.

The researchers recently updated their 25-million-gallon-a-year model for dry-grind ethanol producers to a 40-million-

gallon version, which is available to anyone doing research or in the initial phases of building a plant.—By **Jim Core**, ARS.

*This research is part of Quality and Utilization of Agricultural Products (#306) and Bioenergy and Energy Alternatives (#307), two ARS National Programs described on the World Wide Web at [www.nps.ars.usda.gov](http://www.nps.ars.usda.gov).*

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Using a new computer model, cost engineer Andy McAloon and chemical engineer Winnie Yee discuss different ethanol production techniques and how they might affect costs of producing the fuel.



Chemical engineer Frank Taylor prepares to test fermentability of corn that has been pretreated with a new "ammoniation" process.