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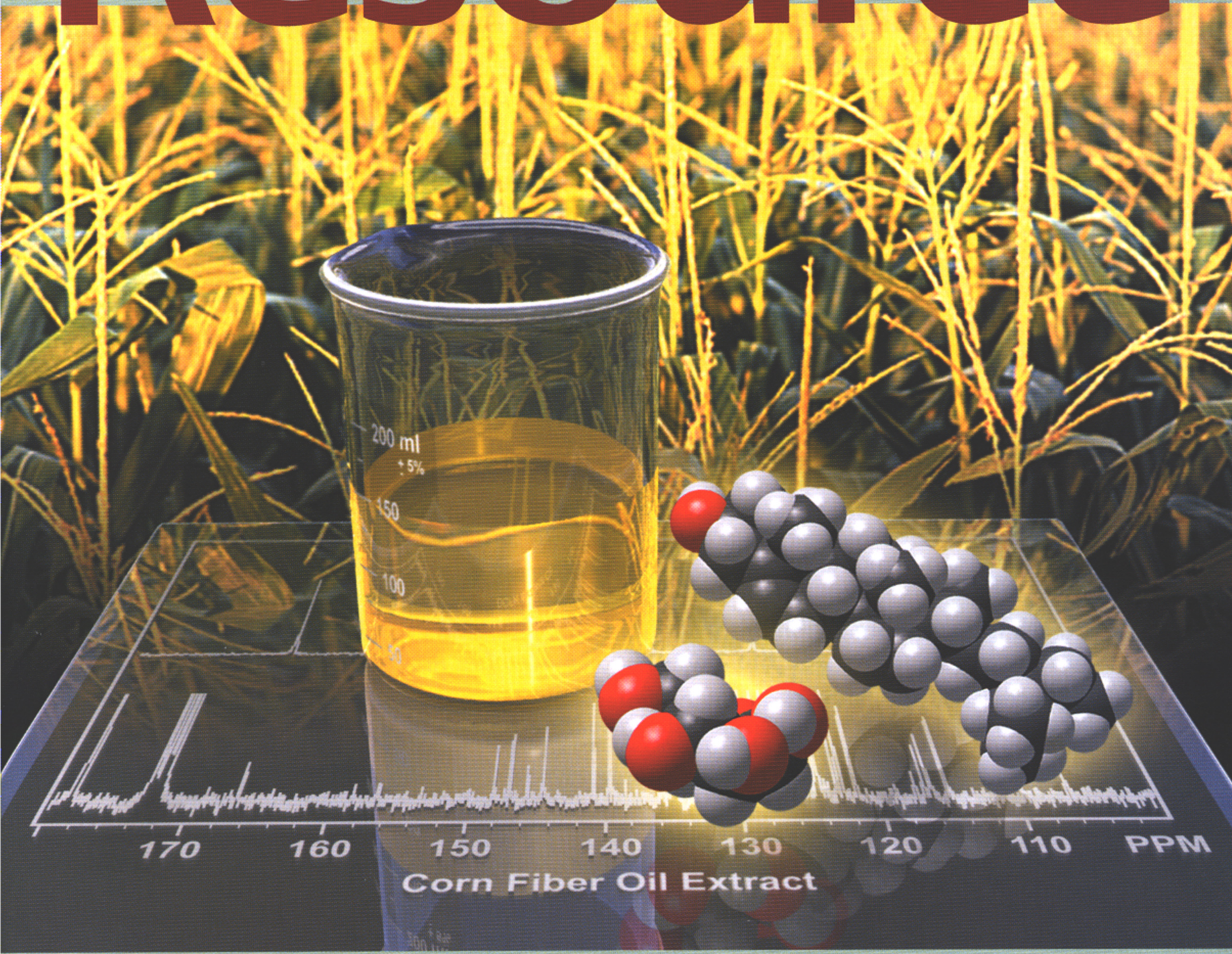

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Profitable to the Last Drop

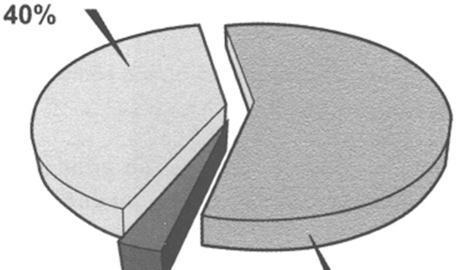
New process captures valuable components from corn fiber

Rick Orth, Charles Abbas, and Rene Shunk

Increasing high-value yield from crops is an ongoing challenge for farmers, agricultural processors, and the bioproducts industry. This is particularly true for corn produced in the United States at the rate of 320 million m^3 (9.2 billion bushels) annually. Of that crop, approximately 49 million m^3 (1.4 billion bushels) are purchased by the wet milling industry for processing primarily into starch, oil, corn gluten feed, and corn gluten meal. The starch is used for industrial and food applications including high fructose corn syrup and ethanol; the oil in food applications; and the corn gluten feed and meal, generally as animal feed.

Corn gluten feed is the lowest-value item in the product stream, typically selling for only $.04 to $.05 cents per pound and competing directly with corn in the animal feed market. This low-priced product accounts for approximately 27 percent of the corn that enters a wet mill and contains approximately 70 to 80 percent fiber. Conversion of the corn fiber to value-added products would greatly enhance the corn crop value on several fronts.

Corn fiber is a low-cost, carbohydrate-rich, readily available feedstock that, as well, could potentially reduce the use of imported petroleum for production of ethanol and other industrial chemicals. The National Corn Growers Association (NCGA), representing growers, and the Archer Daniels Midland Company (ADM), representing processors, have formed a partnership in an effort to divert corn fiber from the feed market and direct it to industrial product markets. The United States Department of Energy (DOE) is providing major assistance. Its Office of Energy Efficiency and Renewable Energy is sponsoring a cooperative research and development agreement through which NCGA and ADM have access to staff and equipment at the Pacific Northwest National Laboratory (PNNL), a DOE Office of Science laboratory in Richland, Wash.



Recovered value from corn fiber.

The NCGA coordinates the cooperative research effort. ADM defines the principal objectives of the engineering effort conducting process development, performing final product analyses, and assessing commercial viability of possible process options. PNNL is collaborating with ADM in process development with ADM. The laboratory is providing key enabling/analytical instrumentation and unique technology in organic synthesis and chemical catalysis.

The three organizations have formed a multi-disciplinary scientific research and engineering team. In just two years, they conducted work in the laboratory that defines a new process for economical recovery of several valuable components from corn fiber. Results to date are very encouraging. NCGA, ADM, and DOE have agreed to undertake a second phase of the project, intended to complete development of the process and demonstrate its viability on a pilot scale. Upon successful completion, NCGA and ADM will deploy the process commercially.

Extracting value from each component

The corn fiber stream is a complex mixture of components, some of which are sensitive to process conditions. The project team has combined applied and fundamental sciences with advanced process engineering for a holistic approach in which the fiber stream is fractionated into its primary components (carbohydrates, oils, protein). Each fraction is recovered in a manner that enables maximum economic utilization of that fraction.

The carbohydrate fraction yields five- and six-carbon sugars, primarily glucose, xylose, and arabinose – the most abundant chemical building blocks in the fiber. The glucose will be used to make fuel ethanol, a product that currently reduces U.S. oil import requirements by almost 76 billion liters (2 billion gallons) annually. Through the new process, ethanol could be produced in sufficient quantity to help achieve the government objective of tripling U.S. ethanol capacity by 2020.

Other sugars can be catalytically converted to propylene glycol and ethylene glycol, chemicals that are used in industrial and consumer products including plastics, polyesters, and antifreeze. Currently produced from petrochemical feedstocks, these chemicals have sizeable U.S. markets. Producing them from sugars could support U.S. policy interests by further reducing petroleum imports.

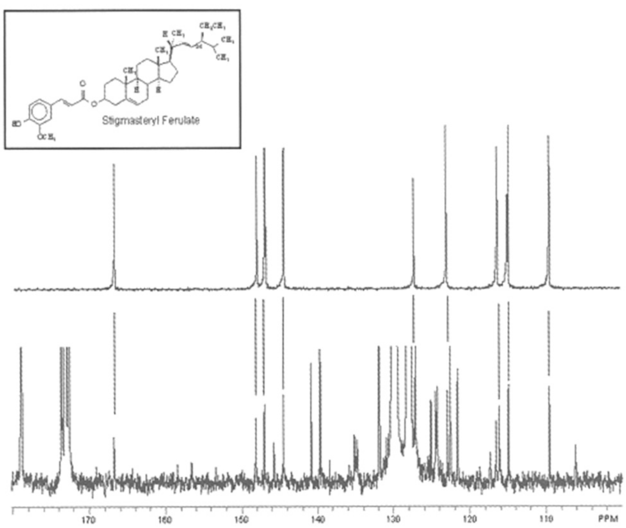
The process also preserves the functionality of the small, but potentially high-value, oil fraction. Of key interest is the recovery of trace phytosterols that have high-value applications as "nutraceutical" food supplements and as "botanical oils" in personal care products. There is limited supply of these oil components; their recovery will help keep pace with consumer demand and contribute significantly to the economic viability of the process.

The recovery of the carbohydrate and oil fractions captures approximately 60 percent of the corn fiber volume for industrial applications. The residual 40 percent is a very high protein mixture – about double the protein content in less than half the bulk compared to the original product – and it should deliver a higher feed value in the marketplace.

Science delivers solutions

Corn fiber contains about 3 percent oil, with 5 to 20 percent of that oil consisting of phytosterols. Because of the potential value of these trace components, it was essential that analysis of the oil be extremely accurate and reliable and that the functionality of the molecules be retained throughout the recovery process.

The first step was crucial: determining the exact composition of the oil fraction. Four months into the project, highly sensitive methods developed at PNNL showed that certain trace components were present and certain others were not. Researchers then focused their efforts on the recovery of components that were confirmed present in the oil.



NMR signatures of a sterol molecule (top) and an entire oil sample (bottom).

Precise and timely analysis was made possible by the laboratory's extensive collection of scientific instrumentation, including an array of nuclear magnetic resonance (NMR) spectrometers, similar to hospital magnetic resonance imaging (MRI) devices, containing high-field superconducting magnets for the study of molecules and cells. These instruments enable researchers to determine the most fundamental information about molecular structure in support of studies of cellular mechanisms, materials science, and chemical processes – including the composition of corn fiber and its trace oils.

NMR analysis produced highly sophisticated identification of the corn fiber oil constituents. Researchers then used another technology – gas chromatographic mass spectrometry – to determine the quantities of each fraction present. Information obtained from these investigations enabled development of a process for recovery of intact phytosterols. The same NMR instruments also proved invaluable in providing microkenetic analyses to identify the optimum process conditions for recovery and conversion of the carbohydrate fraction. The result: a financially attractive "disassembly" process that enables optimal recovery of trace oil components and significant amounts of sugars.

Making the numbers work

Process economics are critical to the ultimate fate of the process. Laboratory results are being used to perform process engineering and economic evaluations, and that information is continually applied to direct further research and process development.

Early laboratory results have yielded promising financial assessments. The next step is to evaluate several elements of the new process on the pilot scale to determine the prospects for commercial success. The pilot phase will begin in 2003 and will continue over 2.5 years, It will include bench-scale process optimization testing, system design, system procurement and fabrication, system assembly, shakedown testing, actual testing, and an economic evaluation of the integrated process. The commercial parties (ADM and NCGA) are leading this phase of process development, and the DOE will continue to provide technical and analytical support through PNNL.

There is much at stake. The new technology could significantly improve supplies of valuable industrial chemicals and transportation fuels. In addition, diverting this fiber from the feed market could improve the value of corn purchased for grind and support the overall value of feed grains – all directly benefiting farmers and processors. **R**

Rick Orth is a senior staff engineer and project manager, Pacific Northwest National Laboratory/U.S. Department of Energy; Charles Abbas is fermentation and bioprocess research manager, Archer Daniels Midland; and Rene Shunk is director of business development & corn processing research, National Corn Growers Association. All are members of the team that has completed the research and development phase of a process to convert corn fiber to highly marketable chemicals and oils, as well as a higher value livestock feed. Visit www.pnl.gov/biobased/ for more information.