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Author(s):	K.B. Hicks, R.A. Moreau, D.B. Johnston, L.W. Doner and V. Singh
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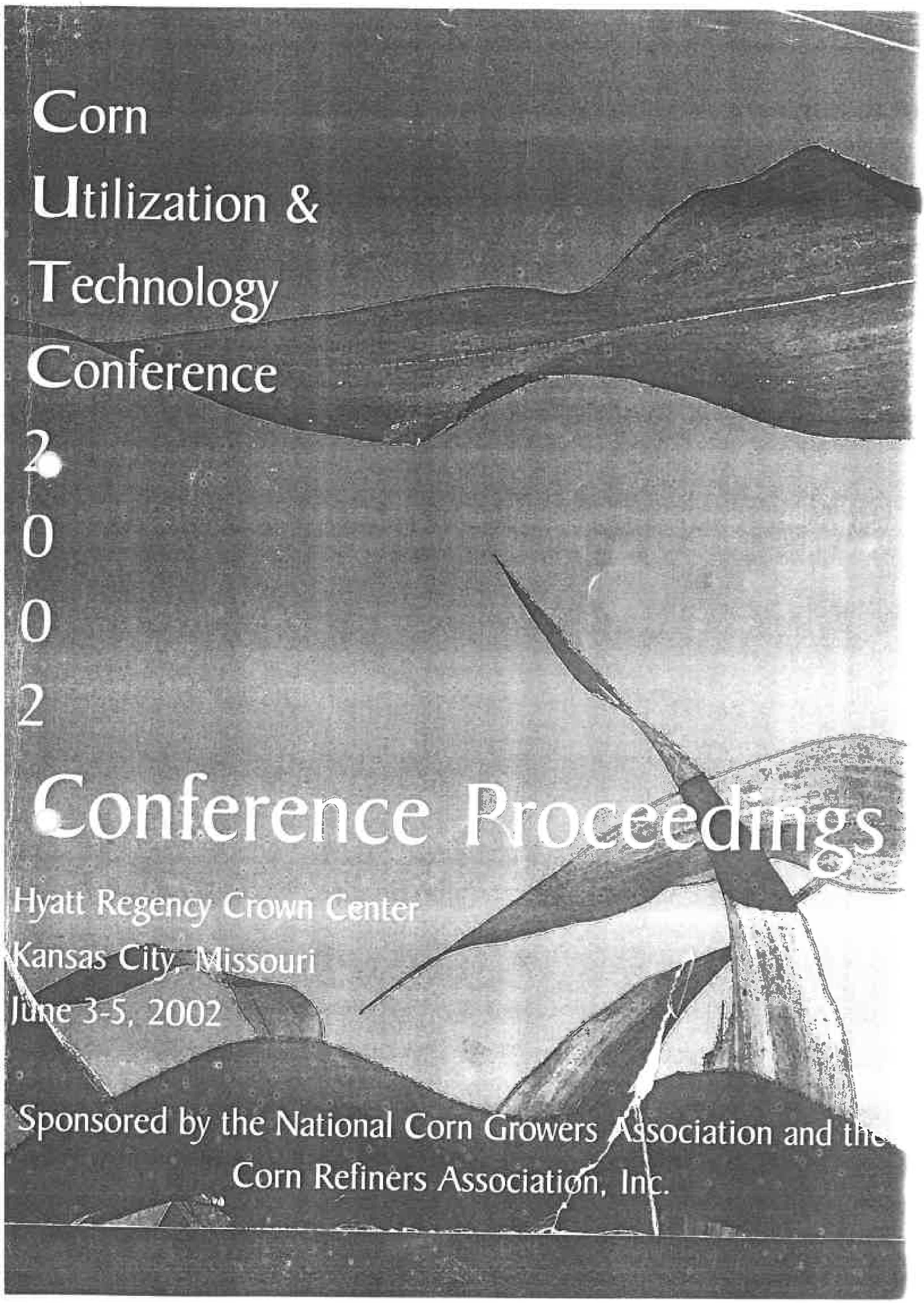

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POTENTIAL NEW USES FOR CORN FIBER

Kevin B. Hicks, Robert A. Moreau, David B. Johnston and Landis W. Doner
Crop Conversion Science & Engineering Research
Eastern Regional Research Center, ARS, USDA
600 E. Mermaid Lane
Wyndmoor, PA 19038
215-233-6579
Email: khicks@arserrc.gov

Vijay Singh
University of Illinois at Urbana-Champaign
1404 West Pennsylvania Avenue
Urbana, IL 61801

ABSTRACT

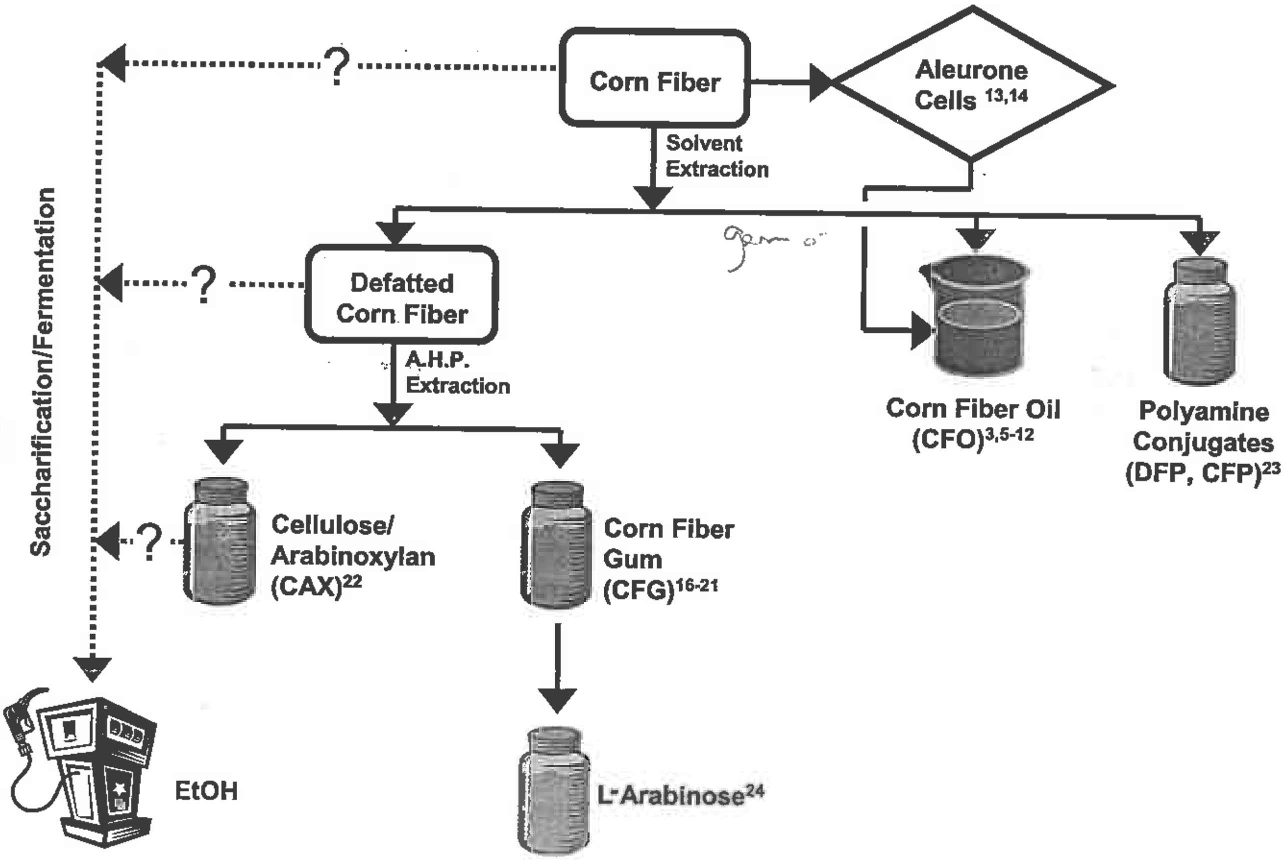
More than 4 million tons[1] of corn fiber is produced each year by current wet milling operations in North America. Current dry grind ethanol plants are producing more than 1 million additional tons[2] of corn fiber, contained in the coproduct, distiller's dried grains with solubles (DDGS). New processes in development for modified dry grind operations, biobased product manufacture and new enzymatic milling processes will generate more and different types of fiber. Rather than treating this fibrous material as the lowest value coproduct from corn milling, we have chosen to look at fiber as one of our most abundant, currently available and renewable feedstocks for the production of biobased industrial products, nutraceuticals, functional food ingredients and biofuels. Examples of potential products derived from fiber include corn fiber gum, corn fiber oil, L-arabinose, polyamine conjugates, cellulose/arabinoxylan products and fuel ethanol.

INTRODUCTION

Our research program on corn fiber utilization at the Eastern Regional Research Center (ERRC), ARS, USDA began in 1994 and is continuing to the present day. During this time, we have completed a number of related studies in this area. The results have been published and patented and made available to industry for the purpose of stimulating development of new food, nutraceutical and biobased industrial products. This paper is not a comprehensive review of corn fiber utilization research but rather, we review major accomplishments from our program plus new processes and products recently developed through our ongoing collaborations with the U. of University of Illinois at Urbana-Champagne (UIUC).

CORN FIBER FRACTIONATION

Scheme 1 outlines the major processes being developed in our laboratories for fractionating corn fiber into value added products. It is unlikely that the isolation of just one of these products (except perhaps corn fiber gum) would be feasible economically but isolation of two or more products in the same process could improve overall product profitability.



SCHEME 1
ERRC/ARS/USDA CORN FIBER FRACTIONATION PROCESS

Corn Fiber Oil (CFO). CFO contains high levels of cholesterol lowering phytosterols[3] that, according to the FDA, can reduce the risk of heart disease[4]. Margarine spreads, cream cheese spreads, yogurt, milk and snack bar products containing phytosterol now are available and growing in popularity worldwide. Current commercial products are derived primarily from soy and tall oil based phytosterols, but growing demand will require new sources. Corn fiber oil can be extracted[5] by organic solvents such as hexane or supercritical CO_2 and, depending upon fiber pretreatment conditions, may contain from 5 to 30% phytosterols, up to 3% gamma tocophero[6], ferulic acid and a variety of carotenoids. The combined LDL-cholesterol lowering and antioxidant effects of corn fiber oil may make it a superior product to current phytosterol products[3]. Oil extracted from corn bran (from traditional dry grind processes) generally is inferior to that from corn fiber (wet mill) in terms of phytosterol concentration[7]. Phytosterol levels in yellow dent corn vary depending upon hybrid type and growth location[8]. Phytosterol levels also vary considerably among germplasm accessions of corn and it's progenitor, teosinte[9] indicating that breeding programs to increase the level of phytosterols in corn is possible. Wet milling conditions[10, 11] including the type or presence of sulfite agent and organic acid, can effect the phytosterol levels in fiber and in the oil. Corn fiber oil, its manufacture and its use are covered by a US Patent[12] which was licensed previously by Monsanto and is now licensed by MBI, Inc. for all applications except cooking oils.

Aleurone Oil. Our previous work comparing the composition of corn bran oil and corn fiber oil[7] and more recent studies on the effects of alternative corn milling practices[11] is suggestive that phytosterols and especially their fully saturated forms, phytostanols, were present in specific but unidentified locations within the corn kernel. Follow-up studies[13, 14] have revealed that the single layer of aleurone cells located between pericarp and endosperm tissue contain essentially all the phytostanols (as ferulate esters) present in corn kernels. Knowledge of the cellular location of phytosterols is leading to a new process[15] for isolating oil enriched aleurone tissue as a new starting material for corn fiber oil extraction.

Corn Fiber Gum. Dried and destarched wet mill fiber contains 50% hemicellulose (arabinoxylan) that can be extracted with alkali and processed to yield a valuable food gum. Nearly all corn wet millers have attempted to develop processes during the last 50 yrs to prepare a commercial food gum but none has been successful. We developed several processes[16, 17] to make a high-quality, colorless, corn fiber gum and have shown that different arabinoxylans can be isolated from coarse and fine fiber[18] and different corn wet milling fiber fractions[19]. The molecular weight, intrinsic viscosity, and radius of gyration of purified corn fiber gum has been studied and reported[20]. A cooperative R&D agreement between ARS and National Starch and Chemical Company led to a jointly owned patent for the preparation and purification of corn fiber gum[21]. It is anticipated that a commercial product will develop from this process.

Cellulose/Arabinoxylan (CAX) Complexes. After defatted and destarched fiber has been extracted exhaustively with alkaline hydrogen peroxide, a white powder resembling pure cellulose is produced[22]. Extensive characterization of this product has shown that it is not, in fact, pure cellulose but that it contains almost one third inextricably linked arabinoxylan. These CAX preparations absorb up to 100 times their weight in water, making them excellent bulking agents. The open structure of the CAX matrix also could render these products suitable for chemical derivatization or enzymatic saccharification prior to fermentation to ethanol by yeast or recombinant, hexose and pentose fermenting organisms.

Polyamine Conjugates. Extraction of fiber with polar solvents such as methylene chloride or ethanol, especially at high temperature, yields the expected corn fiber oil phytosterols plus two unusual polyamine conjuates, diferuloylputrescine (DFP) and p-coumaroyl-feruloylputrescine (CFP)[23]. Corn bran extracted with hot methylene chloride yields an oil containing 14% DFP and 3% CFP. The presence of these conjugates in corn fiber/bran has not been appreciated. It has been suggested that these conjugates may function as natural pesticides; their biological activity is being tested. Other uses for these novel compounds may emerge.

L-Arabinose. Corn fiber is one of the richest available sources for L-arabinose; one of nature's few L-sugars. In fact, starch free corn fiber contains about 25% L-arabinose by weight. L-Arabinose is used in the preparation of chiral drugs and while it commands a high price, the overall market is small. L-Arabinose also may be useful for preparing non-caloric bulking agents to be used with high intensity sweeteners. We have conducted preliminary research[24] that showed crystalline L-arabinose can be produced from corn fiber and corn fiber gum.

NEW MILLING PROCESSES CREATE NEW TYPES OF FIBER

As new milling processes are developed and commercialized, new types of fiber with potentially different composition and uses will be developed.

Quick Fiber Process. The quick fiber process, like the quick germ process developed at UIUC, is a modified dry grind ethanol process. Use of the quick germ and fiber processes removes non-fermentable germ and fiber from the mash prior to fermentation. The germ can be sold for oil extraction and removal of fiber would produce a low fiber DDGS, which may have higher value and wider feed applications. Quick fiber, however, contains much lower levels of phytosterols (25) than conventional wet mill fiber unless SO_2 and lactic acid are added to the short kernel soak period of the quick germ process[25]. Quick fiber also was shown to be equal to conventional wet mill fiber as a starting feedstock for corn fiber gum[25].

Enzymatic Milling Processes. In other research at our laboratory, covered in another presentation at this symposium, we are developing enzymatic processes that may someday replace sulfite in the corn wet milling process[26] and that may also greatly expand the range and value of coproducts from the dry grind ethanol process. The use of these types of fibers for coproduct development is under investigation.

CONVERTING FIBER TO ETHANOL AND REDUCING AMOUNTS OF CONVENTIONAL DDGS

Many private and public researchers are working on conversion of corn fiber to ethanol will increase the ethanol yield from a bushel of corn and will help find outlets for this abundant coproduct. Corn fiber oil can be extracted from fiber without affecting overall ethanol yields. However, extraction of corn fiber gum would reduce the theoretical yield of ethanol by almost 50%. Whether or not this is acceptable, depends on the value of corn fiber gum relative to ethanol. As stated earlier, CAX products are enriched in glucose and have an open structure that would facilitate saccharification to fermentable sugars. Once again, market forces will dictate whether CAX would be used as an ethanol feedstock, or as a fine chemical, bulking agent or other high valued product.

Currently we are participating in a 4 partner collaboration (UIUC, NREL, NCAUR and ERRC) to study the laboratory/pilot scale conversion of quick fiber into ethanol. If this can be successfully done and ultimately commercialized, we would increase the amount of ethanol produced from each bushel of corn, reduce the amount of conventional DDGS produced, and increase the amount of low-fiber DDGS which may have expanded value and feed applications.

TOWARDS COMMERCIALIZATION

Federal laboratories conduct and fund research but do not commercialize products. Our goal is to discover new knowledge, share it with other Federal and non-profit researchers (Pacific Northwest Laboratory, NREL, MBI, Inc.), and to transfer that technology to the ultimate manufacturer. Research and development now being conducted at National Starch and Chemical, ADM, Eastman Chemical, and several other prominent corporations ultimately will determine the success of these potential new uses for fiber in the marketplace.

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