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Thinking Biorenewables? Think Corn!

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Iowa Corn Promotion Board

It all starts with a single seed planted into one of the United States' greatest assets—fertile soil. Next, the greatest natural nanoprocessors in the corn plant shift into production mode. The internal processors take sunlight, CO_2 from the air, moisture from the air and soil, and nutrients from the soil and convert those seeds to the world's largest renewable resource for feed, fuel, fiber, and a whole new carbohydrate economy.

Figure 1 illustrates the composition of a grain of corn. Oil comes from the germ. The starch is the driver for the ethanol industry. The protein becomes gluten, a great feed source. Hull and fiber uses are just now being expanded. Corn processing is basically divided into wet milling on the left side of figure 2, and dry milling on the right side of the figure. Dry milling is less capital intensive and is the milling process used by most farmer-owned ethanol plants. Large corporate plants use the wet milling process to separate more of the different parts of the corn kernel to add value to the whole process. The separation technology is being added to new dry mill plants and retrofitted to existing plants. The value beyond feed for co-products at the end of the ethanol process is becoming very evident.

Ethanol started out as a "new use" more than 30 years ago. If it weren't for corn farmers and their checkoffs, the ethanol industry would have wilted from its critics. Farmers are naturally optimists, and they had the perseverance to stay with this biorenewable thrust even when well intentioned people in industry and government viewed it with disinterest.

In the past 30 years, corn use for ethanol has grown from just 10 million bushels to a projected 1.6 billion bushels this year. In Iowa alone, ethanol production from corn now has 6,000 grower investors—in fact, more than one out of every ten Iowa corn growers is an investor. Its benefits to the broader state economy include 3,700 jobs, a $2.6 million increase in local tax bases, and an additional $841 million in revenues, according to an analysis by economists at Iowa State University.

Looking more specifically at ethanol's economic impact on Iowa's corn growers, ethanol production is adding $2.40 worth of value to every bushel processed. We see the results as $81 million of increased farm-gate income, a statewide improvement in corn basis of 4 to 5 cents, and an improved basis in areas close to the plants of as much as 12 cents per bushel. In addition, the growing supplies of distillers grains from the plants are benefiting Iowa's livestock producers. The boost to rural economies is very evident.

Now let's look at where the carbohydrate economy is taking the world next. Ethanol is only one of many avenues we can explore to replace non-renewable chemicals like petroleum with renewable starch-based products. As you can see in figure 3, we have many opportunities—this is just a snap shot of the some of the possibilities.

One of the more recent successes of research into biorenewables is the corn-based plastic PLA (polylactides). Early research was initiated 18 years ago by the Iowa Corn Promotion

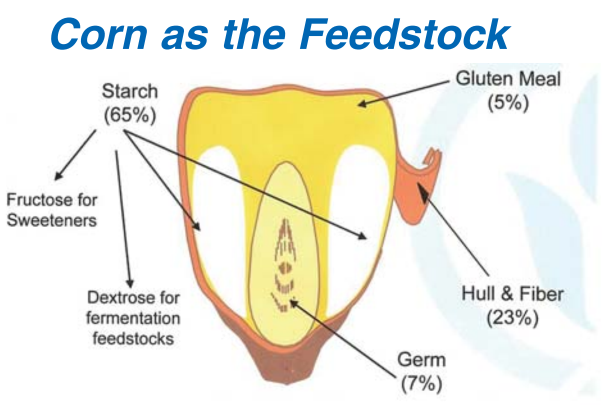

Figure 1.

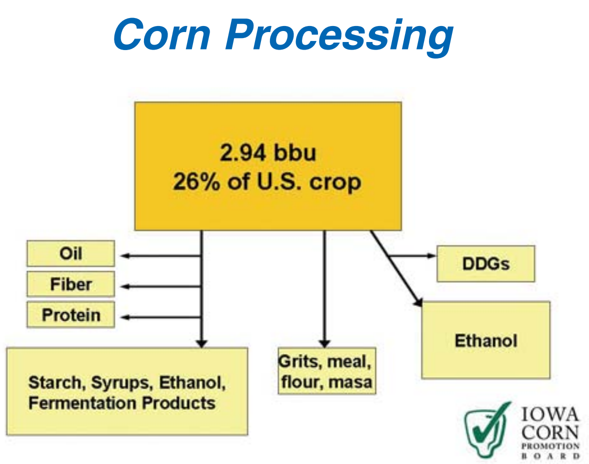

Figure 2.

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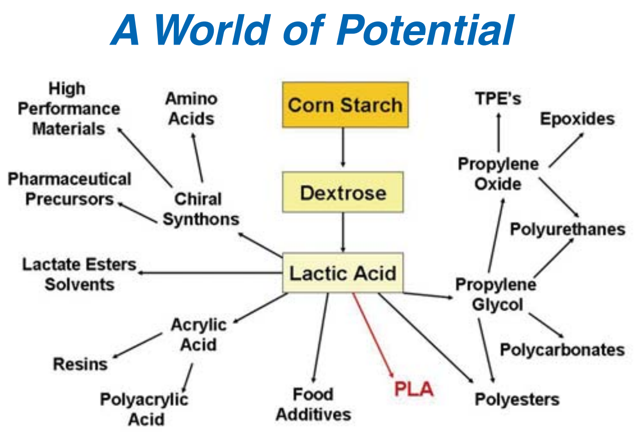

Figure 3.

Board, with additional support from the Nebraska Corn Utilization Board, and the National Corn Growers Association.

Cargill then began work on PLA, which led to construction of the first commercial scale plant at Blair, Nebraska. Full-scale PLA production began in 2001. PLA is now being commercialized in two general areas: in fabrics under the Ingeo trademark and as a resin for packaging and plastics under the NatureWorks trademark.

NatureWorks, now a wholly owned Cargill subsidiary, is currently working with more than fifty companies to introduce PLA-based plastics and packaging in many forms (sheet, film, bottles, jars, rigid food packaging, and service ware) across Europe and in North America, Japan, Korea, Taiwan, Australia and New Zealand.

Ingeo is being introduced in intermediate textile products like yarns and batting and in finished products that include hosiery, apparel, hygienic non-woven products like diapers, fiber-filled products like comforters and futons, and home textiles and furnishings. More than 200 partner companies are involved in this effort, and the geographic reach is even broader than for the resin applications.

Some of the more intriguing applications for PLA include its use in credit, debit, gift, and phone cards, in landscape and plant applications such as fertilizer bags, plant pots, and landscape fabric, and even in the clear plastic sleeves used by florists to protect plants. In Iowa, we now have a company that is making socks from PLA, and in one of the more recent examples of PLA adoption, Wal-Mart began using PLA to

How PLA Is Made

The basic raw materials for NatureWorks PLA are carbon dioxide and water. Growing plants, like corn, take these building blocks from the atmosphere and the soil. They are combined in the plant to make carbohydrates (sugars and starch) through a process driven by photosynthesis. The process for making NatureWorks PLA begins when a renewable resource such as corn is milled, separating starch from the raw material. Unrefined dextrose, in turn, is processed from the starch. Future technology enhancements may eliminate the milling step and allow for the use of even more abundant agricultural by-products.

NatureWorks turns the unrefined dextrose into lactic acid using a fermentation process similar to that used by beer and wine producers. This is the same lactic acid that is used as a food additive and is found in muscle tissue in the human body.

Through a special condensation process, a lactide is formed. This lactide is purified through vacuum distillation and becomes a polymer (the base for NatureWorks PLA) that is ready for use through a solvent-free melt process.

Development of this new technology allows the company to "harvest" the carbon that living plants remove from the air through photosynthesis. Carbon is stored in plant starches, which can be broken down into natural plant sugars. The carbon and other elements in these natural sugars are then used to make NatureWorks PLA.

NatureWorks LLC, a wholly-owned stand alone company of Cargill, manufactures PLA at its plant in Blair, Nebraska. This world-scale production facility allows NatureWorks to meet growing international demand for the product. At full capacity, the production facility will produce 300 million pounds of PLA per year (136,080 metric tons). To produce this, 750 million pounds (340,200 metric tons) of corn (with 15% moisture) are required.

NatureWorks uses Number 2 yellow dent corn, the most common corn variety, with more than 80% of the crop grown to feed animals. No. 2 Yellow Dent corn can also be used to make food products like dextrose and fructose (used as sweeteners in a wide range of food products) and is considered safe as a raw material for human food products.

On average, approximately 2.5 kg of corn (at 15% moisture) are required per kg of PLA (or 2.5 lbs/lb of PLA). The difference (1.5 kg corn) is not all waste. Some is simply water, some of it ends up in other corn wet mill products such as germ oil, corn gluten meal and corn gluten feed, and a part compensates for the yield losses in the different processes.

NatureWorks PLA does not contain genetically modified material, nor does its production require any.

From The World Business Council for Sustainable Development (WBCSD) 2004 Case Study.

The PLA manufacturing plant in Blair, Nebraska.

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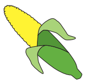
package fresh and cut fruits, herbs, and vegetables and plans to phase in PLA gift cards, deli trays, salad boxes, and film packaging for baked goods.

Because PLA can be used in so many different products at different levels of adoption, it's very hard to translate this into corn use. One indicator that may give a sense of its potential is the latest estimate from experts in Taiwan that use could require 5 million bushels of corn annually by 2009 to serve a nation of 22.5 million people. If you assume the same level of adoption in much larger countries, the equivalent to 5 million bushel use in Taiwan would be 28 million bushels in Japan or 56 million bushels in the United States.

But new uses for corn don't end with PLA. We have maintained an aggressive research program to explore additional new uses. This is not an easy task for a number of reasons. First, the time span for such research is quite long. This work takes many years and depends on strong public-private partnerships to succeed in bringing a new use to market. Also, we've found that a biorenewable product is only sustainable when it has at least equivalent function as the products it is replacing. Most new biorenewable products are reaching or exceeding this standard with the added value of being safer for our environment.

Here are some examples of corn new uses that are moving through the research-commercialization pipeline:



One project to use the corn fiber component more effectively is the polyols work being directed by the National Corn Growers Association, with funding from our corn checkoff dollars and Department of Energy grants. This work involves separating the corn fiber into its component sugars, then converting them into products like propylene glycol, for use in polyester resins, coatings, paints, detergents, cosmetics, and drugs. Annual propylene glycol demand is estimated at 850 million pounds. A second polyol option is ethylene glycol, used in PET and in antifreeze—a 5.6 billion pound market per year.

I know what you're thinking...

Can I drink the beer and then eat the cup?

From the NatureWorks website: While NatureWorks PLA is well suited for food contact and packaging, it is not recommended for human consumption. However, if it is accidentally ingested it will either pass through the body, or break down into lactic acid, which is a naturally occurring substance of the human body. This natural substance is consumed by people every day in a variety of foods and it poses no known health hazards.

Service ware such as this beverage cup is just one of the new uses for corn-based plastic PLA.

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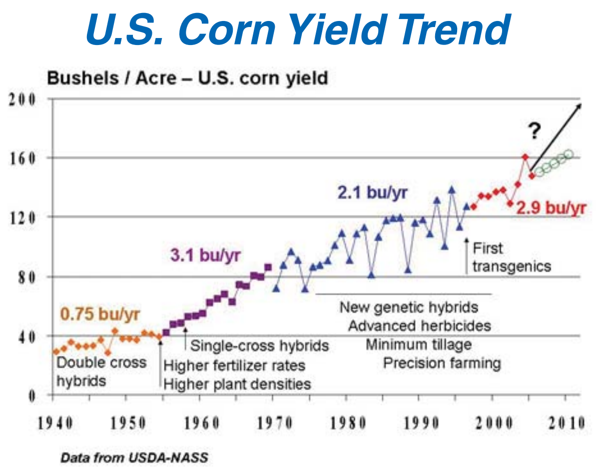

Figure 4.

At the Iowa Corn Promotion Board, we are also funding research with the DOE at Pacific Northwest National Laboratories into the production of isosorbide. Isosorbide would come from the starch portion of the corn kernel and be used as a polymer additive. It has the potential to reduce the amount of petroleum feedstock used in the polymer industry, improve the properties of the plastic, and use an additional 30 million to 40 million bushels of corn per year.

Yes, DaimlerChrysler, Iowa Corn does have a hemi! Hemicellulose fiber, that is. This is another project to convert corn fiber from a dry mill plant into higher value renewable products that include industrial chemicals, plastics, and solvents. This is a joint project with Iowa Corn, Minnesota Corn, Ohio Corn, and DOE. By increasing the value of the corn fiber, this project will also improve the overall economics of ethanol production, potentially by increasing the production of ethanol from an acre of corn by 75 gallons.

Finally, a priority to corn farmers nationwide is the mapping of the corn genome. This will open new doors for functionality studies to examine what further added input traits (drought resistant, new and safer herbicide resistance, insect resistant, better plant heath in general) can be added. Output traits will be wide open. The nano machinery within the corn plant can churn out an unlimited amount of new products when so directed by advancements in bioengineering. Iowa Corn has trait research underway but in this project more than any other, no one can do the job alone.

One question that arises in the push for new uses for corn: Will there be enough corn to meet all the demands? First, it's important to recognize that the conversion of the starch in corn to whatever use still leaves a high protein feed co-product. So the development of many value-added products also results in increased supplies of feed ingredients to support livestock production—and our experience in Iowa ethanol production is that this distillers grain is being readily adopted into feed rations.

Second, corn yield trends are advancing at ever higher rates and will get a big boost from genetic research that will unlock even higher yield potential (figure 4). Improved genetics are having effects already. It's not by chance that although 2005 was the 20th driest year on record, corn yields where the second highest ever.

There are additional factors that contribute to the supply side of the corn equation—factors like the expansion of significant corn production into areas where corn wasn't always a viable crop (such as the Dakotas) and the potential for changes in the crop rotation, perhaps to follow one year of an alternate crop with two years of corn. Finally, we must recognize that corn is not the only potential feedstock for some of these products.

It is obvious why this carbohydrate future is so important to an Iowa farmer. At the Iowa Corn Promotion Board, one of our missions is to move farmers up the value chain and improve profitability back to the farm gate. Will our efforts create a shortage of corn? I don't think we'll see a corn shortage, but hopefully, we will see a shortage of corn at depressed prices that don't return a profit to the grower. As the demand emerges, our nation's farmers will push production to meet that demand. If the U.S. and the world demand biorenewable products, we will meet their needs at all levels.

Julius Schaaf is a farmer director for the Iowa Corn Promotion Board and lives in southwest Iowa, where he raises corn and soybeans. He is an investor in ethanol and biodiesel production and is also a member of the National Corn Growers Association Ethanol Committee and US Grains Council Asia Advisory-Team (A-Team). This presentation was given at the 2006 Agricultural Outlook Forum. ■