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FOLLOW THE MAIZE

Mimi Abebe
University of Nebraska - Lincoln

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From kernel to car fuel: the step-by-step stages of ethanol production.

BY MIMI ABEBE

In the spring of 2008, Nebraska was home to 21 ethanol plants; seven more were under construction.

These plants process corn — a staple in the world's food supply — into fuel for cars, which some believe will be the key to solving our national energy crisis.

The corn, a staple item in the world's food supply, is being transformed into fuel for cars. According to the Nebraska Ethanol Board, "ethanol production has become the third largest use of Nebraska corn — consuming more than 300 million bushels of Nebraska corn harvest annually."

Typically, ethanol plants sit very near their raw material — corn.

York County, in southeast Nebraska, is one of the top corn-producing counties in the state. Each year, 20 million bushels of corn comes into the Abengoa Bioenergy ethanol plant near the city of York. This plant produces 55 million gallons of ethanol a year, said Mitch Stuhr, the plant's manager. But by today's standards, this plant is only middle-sized. The majority of plants being built today can produce 100 million gallons a year.

Long lines of semitrucks pause at the entrance to Abengoa Bioenergy, each truck containing 1,000 bushels of corn from local farmers. To become ethanol, the corn at this dry-milling plant is put through three stages: cooking, fermentation and distillation.

PHOTOGRAPH BY AARON E. PRICE

North Loup, Neb., fields are planted with ear corn.

PROCESS

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COOKING

First, hammer mills grind the corn to reveal the starch within the kernels. Water is mixed with the ground grain to create a mash. The mash is run through a hydroheater and heated to 250 degrees until it explodes.

After the mash is cooled, alpha amylase, an enzyme, is added to break down the bonds of the starch and create a complex sugar.

The mixture is cooled again to 90 degrees Fahrenheit, a temperature that allows yeast to work best during fermentation.

FERMENTATION

Fermentation is the process by which yeast converts sugar into alcohol. Four tanks at the Abengoa Plant ferment mash into alcohol.

To start the process, another enzyme, gluco amylase, is added to the mash. This enzyme changes the complex sugar into a simple one that is easier to process. Yeast is then added.

The products of this process are alcohol, CO_2 — which is released in bubbles — and heat. Beer for drinking has about 6 percent alcohol. After cooling, ethanol beer has about 19 percent alcohol.

DISTILLATION

The next step is distillation, the process of purifying liquid through evaporation and subsequent condensation of the liquid.

First, the alcohol is separated from the ethanol beer. The beer is sent through a series of heated trays to evaporate the water, leaving the alcohol to sink to the bottom of the distillation column.

That alcohol is then run through a molecular sieve that removes the remaining five percent of water.

The water that comes out of this process is distilled water. The alcohol is 190 proof, the highest

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DRY MILLING

In the dry-milling process, corn kernels are ground into flour, and enzymes convert the flour starch into sugars, which are fermented into ethanol. Other products are carbon dioxide (used in the carbonated beverage industry) and an animal feed called distillers grain. Most ethanol plants in the U.S. use this process.
— National Corn-to-Ethanol Research Center

1. Hammer mills grind the grain into flour to release the starch
2. The flour is mixed with water to create a liquid mixture called mash, which is heated
3. Enzymes are added to convert the starch into sugars
4. Yeast is added to the mash, and the mixture ferments into "beer," which contains about 10 percent alcohol
5. The mash moves to distillation columns, where evaporation yields 190-proof ethanol. The ethanol exits the top of the last column, and the solid residue (stillage) is processed into distillers grain, which is used for animal feed
6. A molecular sieve removes the remaining water from the ethanol
7. A small amount of gasoline is mixed with the ethanol to "denature" it, making it undrinkable, thus avoiding the beverage alcohol tax

North Loup, Neb., corn field

proof alcohol possible, very simlar to Everclear, a popular beverage that's notorious for its high levels of alcohol. Unlike Everclear, this alcohol contains methanol, ethanol or isopropyl, elements that can be poisonous.

Once the alcohol has passed through quality-assurance tanks, denaturants are blended in to prepare the alcohol for shipping. The Abengoa plant uses white gasoline as a denaturant to render the alcohol unfit for human consumption. Without this step, the alcohol from the Abengoa plant could be classified as a spirit that could be taxed.

Ethanol fuel is the final product of this process. It is sent to alcohol brokers, blenders, refineries and other places that use ethanol. Ninety percent of the final product is transported by rail. The remaining 10 percent goes by truck.

BYPRODUCTS

The major product of the ethanol-making process is, of course, ethanol, which makes up about one-third of the output of the Abengoa plant. Byproducts constitute another two-thirds of the plant's output: Half of that is CO_2, and the rest is made into feed called distillers grain.

Distillers grain is a high-protein, low-fiber feed. It is usually mixed into other feed such as alfalfa or corn when given to livestock.

The distillers grain can be sold wet, or it can be sold after it is dried.

Abengoa sells wet feed within a 50-mile radius of the plant because the feed has a shelf life of only a week. Dry feed, with a shelf life of up to a year, is sold all over the country for a much higher cost. The Abengoa plant produces about 50 percent dry feed and 50 percent wet feed.

PHOTOGRAPH BY AARON E. PRICE

WET MILLING

In the wet-milling process, corn kernels are soaked in an aqueous medium of water and acid before being separated into starch, protein, germ and fiber. The primary products of wet milling include starch and starch-derived products (e.g., high-fructose corn syrup and ethanol), corn oil and corn gluten. ***— National Corn-to-Ethanol Research Center***

1. Corn soaks or "steeps" in water and acid to enable separating the grain into its parts
2. Grinders remove the germ; the oils in the germ are extracted and refined
3. The remaining fiber, gluten and starch are separated
4. Remaining starch is used for one of three things
5. Starch is fermented into ethanol, dried and sold as corn starch or processed into corn syrup. The fermenting process is similar to that used in the dry-milling process
6. The ethanol is market-ready after a denaturant – often gasoline – is added, making the ethanol undrinkable, thus avoiding the beverage alcohol tax

GRAPHIC BY ALEX HAUTER

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