THE U.S. DRY-MILL ETHANOL INDUSTRY

BIOBASED PRODUCTS AND BIOENERGY INITIATIVE SUCCESS STORIES

Rich Past, Bright Horizons

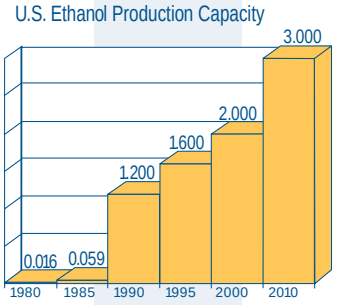
Over the past three decades, ethanol has filled our nation's fuel needs during the oil embargo of the late 1970's, the phase-out of lead in the early 1980's, clean air programs in the 1990's, and the ban of MTBE in the new decade. Ethanol demand has risen from a mere 200 million gallons per year twenty years ago to nearly 2 billion in 2000. It's now a $2.5 billion dollar industry.

In the United States, fuel ethanol is made primarily from corn. Two methods are used to process corn into ethanol – wet milling and dry milling. Dry milling is the most common process used today because of low capital costs required to build and operate these plants. Technological advancements have made dry-mill ethanol plants more efficient and productive than the first generation of dry-mill facilities, which operated in the mid-1980s. Lower energy requirements, more sophisticated automation, lower cost enzymes, advanced yeast strains, and the advent of molecular sieves have cut production costs nearly in half and improved ethanol yields.

More...With Less

Ethanol production today requires about 50 percent less energy than in the early 1980s. During this same period, ethanol yields have increased by more than 22 percent, from 2.2 gallons per bushel of corn to 2.7 gallons per bushel. Also during this time, capital costs to construct an ethanol plant have decreased from more than $2.00 per gallon of annual production capacity to less than $1.50 per gallon.

Continued progress in ethanol production – yield, energy, capital, and operating costs – depends on the development in technology by ethanol producers, vendors of process technology, and government and academic laboratories.



A Long and Colorful History

Ethyl alcohol, or ethanol, has existed since the beginning of recorded history. The ancient Egyptians produced alcohol by naturally fermenting vegetative materials. Also in ancient times, the Chinese discovered the art of distillation, which increases the concentration of alcohol in fermented solutions.

Centuries later, in 1907, Henry Ford re-introduced ethanol to the American motoring public by producing his first vehicle to run on ethanol. The discovery of crude oil and America's ability to efficiently refine it into gasoline caused interest in ethanol as a motor fuel to wane in the early 1900s. In the 1970s, however, the ethanol industry began to reemerge when ethanol was used as a fuel extender during gasoline shortages caused by the OPEC oil embargoes. Later, when gasoline was more plentiful, ethanol began to see widespread use as a cleaner burning octane enhancer, perfect for replacing other, less desirable, gasoline components such as lead.

As a result of clean air regulations, agricultural interests, and energy security needs, U.S. ethanol demand has grown from less than 200 million gallons annually in the early 1980s to nearly 2 billion gallons in the year 2000. This provides opportunities for more dry-mill ethanol production.

The U.S. Department of Energy projects that demand for ethanol will increase to 3.0-3.5 billion gallons per year by 2010 due to the nation's interest in reducing our dependence on foreign energy through domestically-produced renewable energy sources that improve our air quality and reduce global warming.

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The Ethanol Industry TODAY

At the beginning of year 2001, there are 56 U.S. ethanol plants in production and nearly a dozen more plan to come on line by 2002. Nearly 95 percent of U.S. ethanol comes from corn. Of the corn-ethanol plants in operation, approximately two-thirds are dry-mills, producing ethanol, animal feed, and in some instances carbon dioxide (CO_2).

In the beginning – the early 1980's – wet-milling facilities produced most ethanol as a means of adding value to the residual starch stream that remained after separating the other corn components such as oil and germ. But in 1985, the first large-scale dry-mill ethanol plant was built by New Energy Corporation in South Bend, Indiana. It was innovative due to both its size and technology. New Energy is still the largest dry-mill ethanol plant today, with a production of 85 million gallons per year (mmgy).

Dry-mill ethanol plants require lower capital and production investments than wet-mills. The economies of scale are also lower. Therefore, average production capacity for a dry-mill plant is about 30 mmgy vs. 100 mmgy and greater for wet-mills. The lower cost dry-mill facilities make it easier for farmers to raise the capital and resources to build an ethanol plant in their community.

The farming community loves ethanol for its ability to add value to their crops and the positive impacts on the economy and the environment. Many states have adopted programs to encourage production. A recent economic impact analysis on ethanol production, conducted by the State of Minnesota, shows that for every state dollar used to support an ethanol facility, $12.00 - $13.00 returns back to the state's economy.

Statistics for a 15 Million Gallon Per Year Dry-Mill Ethanol Plant

- 28 full time employees
- Payroll of more than $1 million per year
- $300,000 paid in state and local taxes per year
- $22 million in gross revenue per year
- 80 percent of the dollars are spent within a 75-mile radius
- Total economic impact of more than $30 million annually

The Dry-Mill Ethanol Production Process

In dry milling, the corn kernel is broken down, typically in a hammer mill, into a coarse flour-like consistency before it is cooked in water. During the cooking process, enzymes are added to hydrolyze the starch to glucose. The glucose-laden mash is then cooled and transferred to fermenters where yeast is added for fermentation. When fermentation is complete, the alcohol content of the mash (beer) ranges from 12-15 percent on a volume basis.

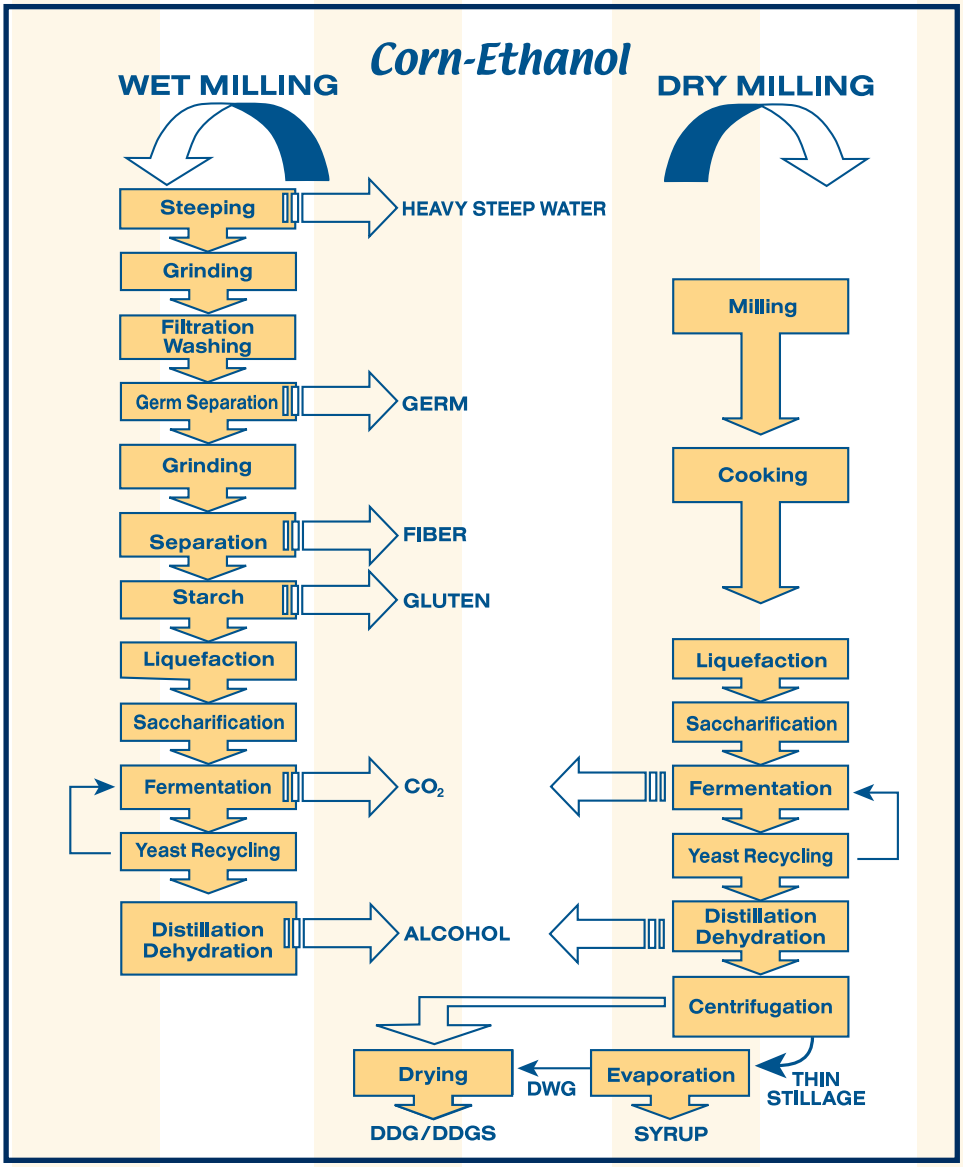
The "beer" is then transferred into a distillation unit where the alcohol is separated from the solids and water. The resulting alcohol-free mash is dewatered in a centrifuge and then sent to the dryer as distillers grains. The liquid from the centrifuge is concentrated in evaporators, and the resulting syrup is mixed in with the dried distillers grains creating a high value feed product.

Yield from a Bushel of Corn from a Dry-Mill Ethanol Plant

2.7 gallons of ethanol
17.5 pounds of distillers dried grains
17 pounds of carbon dioxide

Also…thin stillage (sweetwater) or thick stillage (concentrated distiller's solubles), whole stillage, or blends for cattle feed, according to the process used and the target markets.

Emerging technologies may provide more marketable coproducts in the near term, i.e. germ separation prior to final grinding, and other fermentation products, such as lactic acid, acetic acid, glycerol, etc.



INNOVATIONS in Dry-Mill Ethanol Production

The cost of building a dry-mill ethanol plant has been reduced by 25-30 percent, while the cost of production is nearly half what it was 20 years ago. This is primarily the result of the development of a "fuel-grade" process technology, as opposed to utilizing industrial/beverage grade processes and streamlining production. The following are some of the important innovations used in modern ethanol plants.

MOLECULAR SIEVES: If there is one predominant advancement in the ethanol industry, it is the introduction of the molecular sieve or molsieve. Molsieves have become by far the most popular means to dehydrate ethanol to absolute or near absolute levels. Molsieves are low cost, easy to operate, environmentally friendly, and require little energy (less than 3000 BTU per gallon of ethanol). The molsieve is basically compared to a bed of ceramic-like beads that absorb the water molecules as vaporized ethanol passes through the bed. Molsieves replaced azeotropic distillation systems using cyclohexane or benzene, which were expensive, costly to operate, energy intensive, and posed hazards.

World's largest molecular sieve ethanol dehydrator Photo courtesy of Delta-T Corp.

THERMAL INTEGRATION: Engineering companies are providing turnkey services enabling a more streamlined production process and integrated energy saving technologies. Heating and cooling liquids is part of the ethanol production process, therefore capturing the process heat, and re-using or redirecting it to other areas of the plant significantly reduces energy requirements and costs.

ENZYMES: Improvements in enzyme technology and reductions in the cost of producing enzymes have lowered the price of ethanol by more than 6 cents per gallon. Enzyme manufacturers have increased enzyme production yield 5-fold in the last 15 years. Furthermore, the new enzymes are more productive in hydrolyzing the starches to fermentable sugars and they no longer require the addition of lime for pH balance. Ammonia is now used, providing nutrients (nitrogen) to the yeast, making it more effective during fermentation.

YEASTS: Most ethanol plants today propagate their own yeast. The practice of "pitching," which was the discarding of spent yeast and replacing it with a batch of new yeast, is no longer used. Ethanol plants that previously purchased truckloads of yeast per month now need to purchase only kilograms, primarily for propagation purposes. This has reduced the cost of yeast for ethanol production from about 1.5 cents per gallon to less than 0.5 cents per gallon.

AUTOMATION: System automation has reduced labor costs and improved quality control. While automation may have reduced the number of employees required for an ethanol plant, it has increased the ratio of highly skilled labor. Automation also plays an important role in improving the efficiency and uniformity of the plant and aiding in the quality control process. Product quality contributes to the success of an ethanol plant by delivering a consistent product and building better customer confidence.

Produced by BBI International

MODERN Ethanol Production: Rural Industries + Innovations = Success

Through a combination of innovative technical advancements and process integration, new generation dry-mill ethanol plants have improved yields, reduced costs, and minimized or even eliminated the waste stream (such as the water used in the production process).

Recent growth in the ethanol industry is primarily due to grassroots agricultural support. During the past five years, nearly all of the dry-mill ethanol plants have been built by "new generation" farmer-owned cooperatives. These cooperatives are formed specifically to raise the equity needed to build an ethanol plant in their community.

Chippewa Valley Ethanol Company (CVEC), one of the industry's newest ethanol plants, is a co-op owned dry-mill ethanol plant in Benson, Minnesota. CVEC began operation in 1996 with an initial design capacity of 15 mmgy and has since boosted its capacity to 20 mmgy. The CVEC facility incorporates several innovative design features including zero-process effluent, a flexible batch/continuous fermentation system, and a high degree of process energy integration.

CVEC and their technology partners are continuously improving operating efficiencies in dry-mill ethanol production. Over its four-year history, it has increased ethanol yields from 2.60 to 2.74 gallons per bushel, improved its energy use from 42,000 BTU to less than 36,000 BTU per gallon ethanol, and reduced its chemical costs by 25 percent.

Dry-mill ethanol plants have also optimized the economics of ethanol production through vertical integration. For example, Reeve Agri-Energy in Garden City, Kansas, constructed its 10 million gallon per year ethanol plant adjacent to a large cattle feedlot, where they supply 100 percent of their distillers grains, a high protein feed, to the livestock. In addition, they have incorporated an aquaculture process, raising thousands of Tilapia fish that are sold in local and regional markets. The warm, nutrient rich effluent from the plant provides an ideal growing environment for the Tilapia.

Chippewa Valley Ethanol Company, a 20 million gallon per year ethanol plant in Benson, Minnesota.

FUTURE Technologies

HIGH GRAVITY FERMENTATION: This evolving technology will provide the opportunity to ferment "beer" mash containing considerably higher levels of solids. In doing so, it will reduce the amount of water required, which will then reduce the cost of handling and treating the water later in the process. In addition, higher solids result in higher "beer" yields in the same or less time.

HIGH TEMPERATURE YEAST: The development of yeast strains that withstand higher temperatures will not only increase the alcohol content of the beer but also reduce energy costs.

QUICK STEEPING: The quick-steep process may evolve to be a major change for the dry-mill ethanol industry. Presently, the entire kernel of corn is processed, sending all of the corn oil into the distillers dried grains. The quick steeping process will allow dry-millers to capture the corn oil prior to processing and to sell it as a separate product.

NEW STRAINS OF GRAIN: A 56 pound bushel of corn contains about 33 pounds of starch. In the near future that same bushel may contain as much as 37 pounds of starch through improved hybrid corn. This would result in a gain of more than $2 million in annual revenue from processing the same bushel of corn in a 30 million gallon per year facility.

On the horizon is the promise of a whole variety of new feedstocks using cellulose-ethanol technology. Exciting new developments are underway to convert crop residues, municipal solid waste, forest undergrowth, bagasse, switchgrass, and a host of other biomass materials into ethanol. The existing corn-ethanol industry will be able to expand production by maximizing components of their feedstock. Cellulose-ethanol technology will enable them to convert the corn kernel fiber, cobs and stover into ethanol at a low cost.

Clearly, dry-mill ethanol production is not the same as it was 20 years ago. Industry has responded and will continue to respond with innovations to improve the cost of production to be more competitive in the fuels marketplace. With consumer demand for domestically produced, cleaner burning, and renewable sources of fuel, ethanol will continue to be an important part of America's energy future.