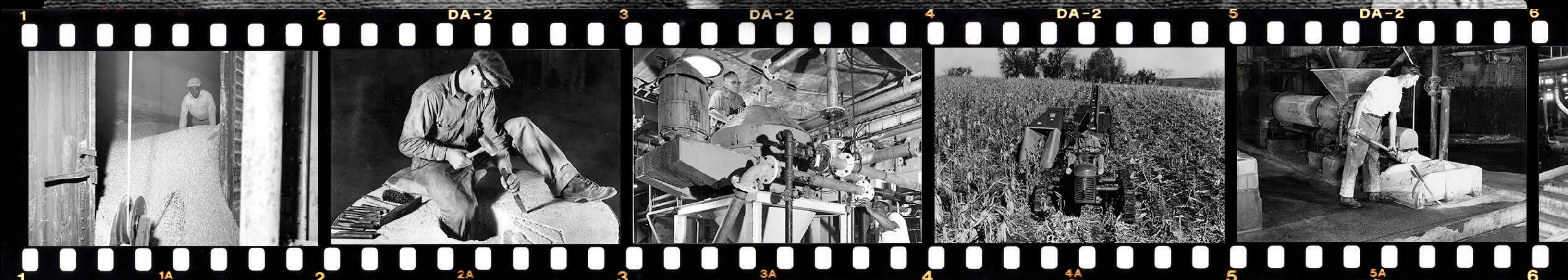
CELEBRATING

CORN REFINERS ASSOCIATION

1913 - 2013

100 Years



Corn Refiners Association 2013 Annual Report

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Foreword

John W. Bode, President & C.E.O., Corn Refiners Association

This year, the Corn Refiners Association celebrates its 100th anniversary. During this time, engineering developments have improved plant efficiency, product quality, and consumer choice. Today, refined corn ingredients offer significant functional characteristics enabling a wide range of products that enrich consumers' lives in a myriad of ways, including through food, pharmaceutical, and industrial applications.

The corn wet milling industry has been an integral component of American manufacturing for nearly 170 years. As the industry grew from one small mill to a thriving group of corn refining companies, industry leaders formed the Associated Manufacturers of Products from Corn in 1913. In the 1930s, the group was renamed the Corn Industries Research Foundation recognizing the major contribution being made by the group to development of starch chemistry and technology. In 1966, the group was renamed the Corn Refiners Association reflecting the broad diversity of products produced by the industry.

As the organization celebrates its 100th anniversary, it is a time to reflect on the legacy of the corn wet milling industry. Many hard-working, imaginative, innovative individuals helped build the industry — developing and perfecting products made from corn — transforming it into starches, sweeteners, fuel alcohol, oil, and bioproducts. With this edition of the *Corn Annual*, we aim to salute an exceptional industry by illustrating the progress that has been made in both the products of the industry and efficiencies gained in the manufacturing process.

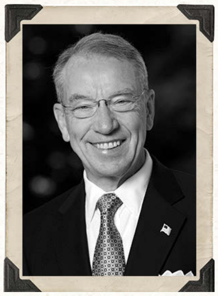
We are very pleased to welcome the Honorable Charles Grassley from Iowa as our featured guest author to help us commemorate this milestone in our Association's history. Iowa is the top corn producing state and is home to more corn wet milling plants than any other state. It is also home to a significant number of corporate, academic and government researchers and scientists who are finding numerous new uses for corn. Senator Grassley shares his intimate knowledge of Iowa's corn industry and how it has played an integral role in the history of the wet milling industry.

I am privileged to take part in this celebration of an organization that has supported the industry through a vastly changing and challenging landscape — from helping navigate trade relationships to developing quality systems for use by the industry. I am sure that we would not have reached this momentous occasion if it were not for the strength of an industry comprised of so many dedicated, hard-working people. I am proud to be part of an industry that realizes the importance and the long-term benefits of its role in providing jobs and innovative products for consumers, while helping maintain our environment and bolstering the national economy. It is an industry with a rewarding past and a bright future.

While we pause to celebrate our anniversary, we look forward to the contributions our industry will make in the next 100 years.

"*Amaizing*" Advances Refresh Iowa's *Cornucopia* in the 21st Century

U.S. Senator Charles E. Grassley of Iowa



In the last century, farm families in Iowa have cultivated tens of billions of bushels of corn to help feed and fuel the world.

The amazing versatility of this invaluable row crop helped sustain rural families generations ago when every last kernel and cob were sold to local merchants, fed to livestock, utilized as bedding, or used to heat kitchen stoves.

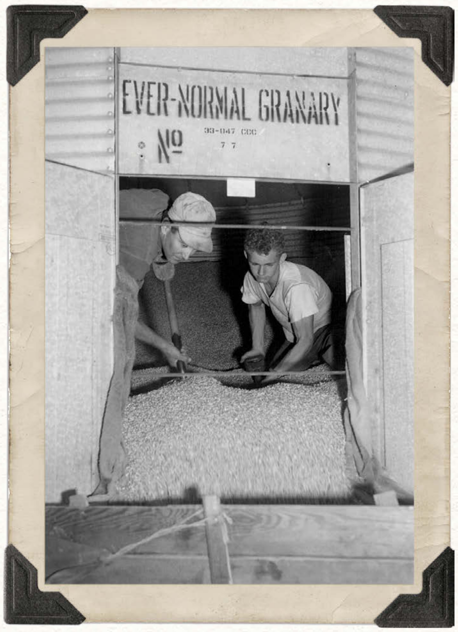
As the Corn Refiners Association celebrates its 100th anniversary, let's take stock of the "*amaizing*" strides Iowa's corn industry and wet milling sectors have yielded in the last century.

- A century ago, Iowa farmers produced 364.5 million bushels of corn per year with an average yield of 37.5 bushels per acre. Today, Iowa corn production exceeds 2 billion bushels annually with average yields reaching 170+ bushels per acre. Industrial-sized grain bins with specialized grain drying and conditioning systems have replaced the open-air corncribs that once dotted the rural Iowa landscape.
- Home to seven wet milling plants, Iowa's eighth facility is scheduled to open for business later this year. The industry in Iowa dates back to Keokuk's mill built in 1887. The state-of-the-art wet mill in Fort Dodge will come on-line with modernized systems to get even more added value out of every kernel.
- In 1921, a wet milling facility in Cedar Rapids developed and patented the first "bottling up" technology which recycles water during an enclosed milling process and extracts greater recovery of co-products.

Shipments of Products of the Corn Refining Industry – 2012

Starch Products *(includes corn starch, modified starch and dextrins)*	5,812,992,000
Refinery Products *(includes glucose syrup, high fructose corn syrup, dextrose, corn syrup solids, maltodextrins)*	29,822,713,000
High Fructose Corn Syrup 42%	7,742,297,000
High Fructose Corn Syrup 55% and Above	11,458,285,000
Total High Fructose Corn Syrup	19,200,582,000
Total — Domestic Basic Products	35,708,563,000
Total — Export Basic Products	5,383,882,000
Corn Oil — Crude and Refined	1,122,959,000
Corn Gluten Feed and Corn Oil Meal	10,415,973,000
Corn Gluten Meal	2,212,153,000
Steepwater	1,733,622,000

Compiled for the Corn Refiners Association by Veris Consulting, Inc. Statistics represent shipments by members of the Association. Shipments are in pounds, commercial weights, and do not include co-products derived from ethanol production.



- Today, the wet milling industry in Iowa helps to employ nearly 6,000 workers with a payroll exceeding $270 million. Those paychecks support families and businesses up and down Main Street, helping to keep local communities vibrant places to live, work and prosper.

Thanks to an impressive brew of conscientious stewardship, soil and water conservation, innovation, mechanization, hybridization and plant genetics, today's farmers, agronomists and entrepreneurs in Iowa are following in the footsteps of the giants of agriculture who came before them. From new wet milling technologies that capture higher starch yields to plant genetics that naturally tolerate herbicides and advanced biorenewable sciences that produce cellulosic ethanol from crop residue, the captains of Iowa's corn industry are blazing new trails to reap even more benefits from Iowa's number one row crop.

For generations, corn has anchored a key segment of Iowa's value-added farm economy. As a leading livestock producer, Iowa's *corn*ucopia has provided farmers an in-house source of grain to fatten hogs and cattle for market. The win-win situation also yields nutrient-rich livestock waste, which provides natural fertilizer to replenish soil health and boost yields for the next crop season.

American agriculture has long helped improve the balance of international trade receipts, with roughly one of every five rows of corn planted for export. And the domestic corn market benefits from demand for high-protein meat; renewable, clean-burning fuels; and the infinite industrial uses newly discovered and waiting to be unlocked by our best and brightest agronomists, engineers and food scientists.

Groundbreaking research and entrepreneurship took root in Iowa more than a century ago when inventors developed machines to harvest corn more efficiently. Before the turn of the 20th century, Patrick Lawler launched his design for the first corn picker and John Froelich built a gasoline-powered tractor that pioneered an incredible success story now known as the John Deere Tractor Works.

Iowa's business, farm and political leaders have long recognized not to underestimate the golden opportunity that agriculture brings to our state's economic outlook and long-term prosperity. The Iowa state legislature was the first-in-the-nation to accept the provisions of the "Morrill Act" of 1862, which created the federal land-grant law to establish colleges dedicated to agriculture, science and engineering. Today Iowa State University has established itself as a premiere research and academic institution employing world-class faculty and graduating elite professionals in biological sciences, engineering, physical and materials sciences, computer and information science, food science, biorenewable resources and sustainable agriculture.

A legendary scientist at ISU from 1939-1958 developed a corn-breeding program that ranks among agriculture's most shining achievements. George Sprague, an ISU-USDA agronomist, is one of the fathers of modern maize breeding and genetics research. Lines from his Stiff Stalk Synthetic, which produced higher yields, strong roots and stalks, and disease- and insect-resistant corn, are responsible for nearly half of U.S. corn hybrids today.

Arguably, Iowa's most renowned plant scientist and humanitarian, Norman Borlaug, helped turn impoverished nations suffering from food deficiency into self-sufficiency through his work on high-yield grains. Dr. Borlaug's lifelong pursuit of food security is credited for saving hundreds of millions of lives from starvation. His legacy continues to feed the world, including ongoing research at the International Maize and Wheat Improvement Center that brings high-yield, drought- and disease-resistant grains to farmers around the world.

With proper stewardship and conservation, Iowa's *corn*ucopia will grow as an infinite resource to help cultivate the economy, advance world food security and protect national security. More breakthroughs in biorenewables will continue to help displace foreign petroleum at the pump and in our factories.

Considering the "*amaizing*" advances achieved in the last 100 years and already underway today, the horizon looks even more promising for Iowans to nurture the corn industry's legacy in the 21st century.

Exports of Products from Corn – 2012

Product	Volume	Units	Value
Corn meal	131,046.7	Metric tons	$66,206,000
Corn starch	158,253.0	Metric tons	$96,436,000
Corn oil, crude	302,508.2	Metric tons	$385,780,000
Corn oil, once refined	16,504.2	Metric tons	$23,898,000
Corn oil, fully refined	176,125.0	Metric tons	$258,749,000
Glucose (dextrose)	110,732.4	Metric tons	$77,081,000
Glucose syrup not containing fructose or containing in the dry state less than 20% fructose	453,279.3	Metric tons	$214,254,000
Glucose syrup with 20–50% fructose	237,821.2	Metric tons	$82,098,000
Chemically pure fructose	71,042.8	Metric tons	$69,059,000
Fructose syrup with 50%+ fructose	1,553,270.7	Metric tons	$634,470,000
Fructose solids containing more than 50% fructose	48,789.3	Metric tons	$66,961,000
Bran, sharps, and other residues	450,041.0	Metric tons	$87,933,000
Corn gluten feed	795,048.0	Metric tons	$184,129,000
Corn gluten meal	925,808.0	Metric tons	$575,961,000
Other residues of starch manufacturing	104,290.0	Metric tons	$ 28,754,000
Corn oil cake	56,866.7	Metric tons	$17,980,000
Dextrins	23,597.4	Metric tons	$20,149,000
Modified starches derived from corn starch	306,633.5	Metric tons	$269,560,000

Source: U.S. Census Bureau Trade Data

From Starch to Bio-products: The *Evolution* of Products of the *Corn* Refining Industry

There is something remarkable about an industry that has found thousands of applications for a plant we take for granted. For nearly 170 years, corn refiners have been developing and perfecting products made from corn – transforming it into starches, sweeteners, fuel alcohol, oil, chemical feedstocks and bioproducts with a growing range of end uses. Relying on science and imagination, corn refiners have built an impressive line of products all stemming from the demand for starch.

Birth of the U.S. *Corn* Refining Industry

Corn refining began in the United States around the time of the Civil War with the development of the process for corn starch hydrolysis by Thomas Kingsford. Kingsford was working at the Wm. Colgate & Company wheat starch plant in Jersey City, N.J. The process used for making wheat starch involved a 14 to 20-day steep in lukewarm water, which produced foul smells and low-quality starch. Kingsford resolved to find a better method for producing starch. He convinced his employer to try a new procedure for extracting starch from corn by treatment with alkaline solutions. In 1844, the Jersey City plant became the first dedicated corn starch plant in the world. A few years later, Kingsford moved on to build his own corn wet milling plant in Oswego, N.Y. By 1857, the corn starch industry reached significant proportions in the U.S. Starch was the only product, and the industry's largest customer was the laundry business.

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The next major event in the history of corn refining was the production of glucose from corn starch in 1866. Applying the techniques of acid hydrolysis of starch that the German chemist G.S.C. Kirchhoff had developed in 1811, early refiners found ways to open new markets and uses for starch. This industrial application and subsequent developments in the chemistry of sugars served as early scientific links to a growing body of starch technology. Other product developments in corn sweeteners took place more than 15 years later with the development of a process for making a crude form of crystalline dextrose (also called refined corn sugar). Manufacturing of the new sweetener began in 1882. In 1921, a process was developed for manufacturing crystalline dextrose hydrate, which was a great improvement over the earlier crude sugars. The purification and crystallization of dextrose meant for the first time that corn based sweeteners could compete in some markets that had been the sole domain of the sugar industry.

The corn refining industry began to realize the value of the non-starch components of corn in the 1880s. The development of a process for separating germ from the rest of the components of the kernel led to new products. Fiber, germ and protein from the corn had simply been discarded until it was discovered that they could be turned into valuable animal feed ingredients. Refiners began to focus on yield of total solids and looked for ways to improve recovery. Corn gluten feed was first manufactured in 1882.

The industry then discovered that corn oil could be extracted from the germ. The first commercial production of corn oil took place in 1889. Then in 1893, the industry began to recover the steepwater used to release the starch in the refining process and condense it to use in feed products.

Major strides in starch chemistry and the introduction of modified food starches, as well as many important process refinements, took place in the early 1900s. In 1900, the manufacture of thin boiling starches was introduced and chlorinated starches were introduced about 15 years later. Waxy-maize starches were developed in the early 1940s. In following years, chemical modifications were discovered that produced a variety of derivitized waxy-maize starches, which were widely used in the printing and food industries. Between 1945 and 1955, further developments in starch chemistry produced cross-linked waxy-maize starches, cationic starches and hydroxyethyl starches.

Enzyme Technology in Corn Sweetener Development

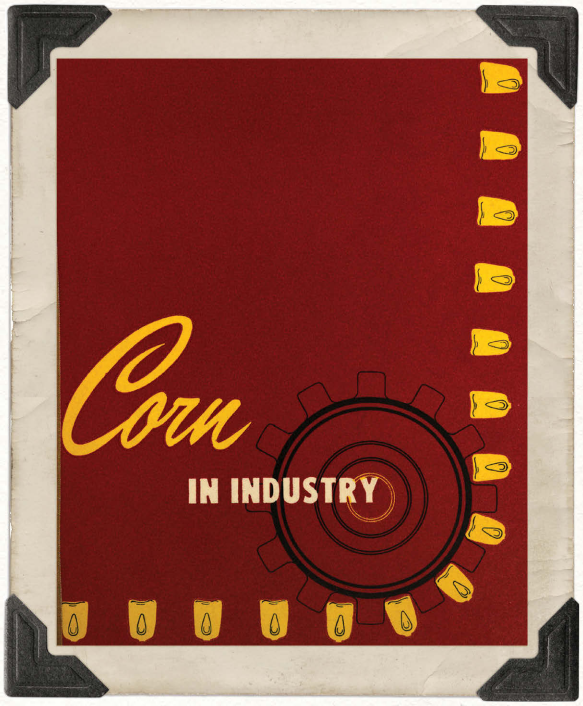
Corn syrup technology advanced significantly with the introduction of enzyme-hydrolyzed products. A patent was issued in 1940 for acid-enzyme hydrolysis describing significant improvements in the conversion of starch to sweetener. A wider range of syrup compositions was possible than from acid hydrolysis alone. Dextrose concentrations of 94 percent were attainable for the first time resulting in sweeter syrups. Undesirable side reactions producing color, off-flavor and degradation products were also substantially reduced. Then in the mid-1950s, the technology for commercially preparing low conversion products such as maltodextrin and low dextrose equivalent (DE) syrups was developed.

During the 1950s, developments in machinery used in sweetener purification led to better quality and higher purity syrups. Rotary vacuum precoat filters

U.S. Corn Refining Industry at a Glance—2012

Corn Refining Plants	26
Location	11 states
Corn Grind	1.55 billion bushels
Value of Corn Purchased	$10.34 billion
Number of Corn Suppliers	41,000
Employment by CRA Member Companies	65,300*
Capital Investment *(replacement value)*	$17.40 billion
Major Products *(estimated)*	
Sweeteners *(dry weight)*	26.73 billion pounds
Starches	8.00 billion pounds
Ethanol	1.21 billion gallons
Co-products	27.08 billion pounds
Value Added by Manufacture	$7.72 billion

*Includes employees that provide services in non-corn refining areas.
Compiled by the Corn Refiners Association based on 2012 data from the U.S. Department of Agriculture, Bureau of Labor Statistics, LMC Commodity Studies, Renewable Fuels Association, press reports, and industry data compiled for CRA by Veris Consulting, Inc.



replaced filter presses used to remove protein and fat impurities. The filters and vacuum pumps proved to be mechanically superior and reliable, and the system provided better syrup clarity. Another development in syrup refinement that took hold during the 1950s was the use of ion exchange. The ion exchange units were used along with carbon filtration to soften and demineralize corn syrups to improve color and heat stability and reduce haze.

A minor revolution took place in the early 1960s with the development of glucoamylases, which enabled a more complete hydrolysis to glucose after the initial acid conversion of starch. The consequent higher purity led to an easier crystallization and better yields. The 1960s also saw the introduction of heat-stable, bacterial α-amylases, which had a more specific action pattern than the acid conversion. The heat-stable enzymes produced high purity glucose.

The next developments involved enzyme catalyzed isomerization of dextrose to fructose. The first commercial shipment of high fructose corn syrup (HFCS) took place in 1967. The product was isomerized batch-wise with a soluble enzyme, which resulted in syrup with a fructose content of around 15 percent. Further research enabled the industry to develop a higher conversion and the first commercial shipment of HFCS-42 or 42 percent fructose syrup took place a year later. During the late 1970s, the commercialization of chromatographic enrichment systems allowed concentration of fructose to 90 percent or higher. Subsequent blending with 42 percent fructose syrup led to the development of HFCS-55. By the mid-1980s, HFCS-55 became the sweetener of choice for the soft drink industry in the U.S.

The same fractionation systems originally developed for producing HFCS-90 led to the commercial success of corn-based crystalline fructose and the economical production of corn syrups with high DE levels and excellent clarity.

Expansion of the Product Portfolio

Starch, glucose and dextrose are still core products of the wet milling industry. But the products of microbiology – fructose, ethanol, food additives and chemicals – have overshadowed them. New technology and research has significantly expanded the industry's product portfolio. Advances in process engineering and biotechnology have enabled refiners to become low-cost suppliers of basic food and chemical ingredients opening new markets in the food and industrial sectors.

The production of ethanol by corn refiners began before World War II, but major

quantities were not manufactured until the 1970s. During WW II, ethanol was used as a process aid in the manufacture of rubber and as a fuel extender. After the War, the necessity and economic incentives of producing ethanol faded and corn refiners focused on core products. The oil embargo of the 1970s resulted in a renewed interest in ethanol as a gasoline additive. Several corn refiners began fermenting dextrose to make beverage and industrial alcohol. The industry has invested in technology to make the process economical and a viable portion of the expanding product portfolio. Cleaner burning diesel fuels have also been made possible by using ethanol as an additive.

The pure strains of sugars produced through chromatographic separation combined with enzyme technology developed during the 1960s and 1970s opened a new line of products to corn refiners. The industry found that sugar alcohols could be economically produced via catalytic hydrogenation followed by chromatographic separation. Previously, production of sugar alcohols was dominated by the chemical industry with corn refiners supplying the base material dextrose. Sugar alcohols produced by corn refiners today include sorbitol, xylitol, mannitol, maltitol, hydrogenated starch hydrolysates and erythritol.

Production of organic acids was also an area dominated by the chemical industry prior to the enzyme revolution in the corn refining industry. Over the last 20 years, the industry has gone from a supplier of raw materials to producing a majority of organic acids for the world market. Citric acid is the most widely used and produced organic acid. The most common method used by corn refiners to produce citric acid is submerged fermentation of glucose. Lactic acid is produced through a similar fermentation process. Other organic acids produced by corn refiners include itaconic and gluconic acid. Amino acids from corn provide a vital link in animal nutrition systems. In the past 25 years, corn refiners have developed fermentation processes to economically produce lysine, threonine and tryptophan for feed supplements. Lysine, an essential amino acid for the growth of nonruminant animals, is used as an additive in swine and poultry production around the world.

Cyclodextrins have been known in the scientific community for over 100 years, but production was limited due to cost and limited application opportunities. Cyclodextrins are enzymatically modified starch derivations. The introduction of cyclodextrin glycosyltransferase opened

Safety Program Award Winners

Incident Rate Excellence Award

(formerly the Outstanding Safety Award)

Archer Daniels Midland Company
– Marshall, MN

Cargill, Incorporated
– Wahpeton, ND

Ingredion Incorporated
– Bedford Park, IL

Tate & Lyle Americas
– Lafayette, IN

One Million Hour Award

(formerly the Distinguished Safety Award)

Archer Daniels Midland Company
– Clinton, IA

Tate & Lyle Americas
– Lafayette, IN
– Lafayette - Sagamore, IN

Zero Lost Workdays Award

(formerly the Safety Achievement Award)

Archer Daniels Midland Company
– Marshall, MN

Cargill, Incorporated
– Cedar Rapids, IA
– Memphis, TN
– Wahpeton, ND

Ingredion Incorporated
– Bedford Park, IL
– North Kansas City, MO
– Stockton, CA
– Winston-Salem, NC

Tate & Lyle Americas
– Lafayette, IN
– Lafayette - Sagamore, IN

the prospect of cyclodextrin production to corn refiners in the late 1980s. Since then, cyclodextrins and their uses have been researched extensively. Flavor encapsulation with β-cyclodextrin is a common usage in the U.S.

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Resistant starches are a relatively new product that are finding a niche in the marketplace. Resistant starches are not digested in the small intestine and function like dietary fiber. They are used as bulking agents in reduced-sugar or reduced-fat food formulations.

Other products currently on the market, but still in the market development stages focus on environmental alternatives to petroleum-based materials. Biodegradable packaging peanuts are produced by changing the physical properties of corn starch through extrusion. Biodegradeable and energy efficient caps, cups, paper coatings, fabrics, carpeting and agricultural mulch films are all possible today because of three types of corn-based polymers. Production of these corn-based polymers uses up to 68 percent less fossil fuel than comparable traditional plastics manufacturing and generates up to 55 percent fewer greenhouse gas emissions.

- Polylactic acid (PLA), a derivative of lactic acid, can be made into commercial-grade plastic products offering price-competitive alternatives to products made from non-renewable resources. The material can be made into fabrics, carpet, cups, food containers, packaging and furnishings.
- Bio-based 1,3 propanediol (Bio-PDO™) is made through a dextrose-based fermentation process. The corn-based propanediol has a wide range of industrial applications including polyurethanes, engine coolants and deicing fluids. It also has a number of consumer applications where it is used as an alternative for glycol in cosmetics and personal care items and in laundry and cleaning products. It can also be used in the production of three carbon glycol terephthalate or 3GT, which can be made into fabric with silk-like qualities.
- Polyhydroxyalkanoate polymers (PHAs) are also made through fermentation. These polymers are very versatile as well as biodegradable in seawater, soil and composting facilities.

Corn refiners will continue this dynamic product evolution by combining technologies rooted in the history of the industry with new technologies from outside the industry to create new markets and greater product diversity.

Corn Refiners Association Member Companies Products

	Archer Daniels Midland Company	Cargill, Incorporated	Ingredion Incorporated	Penford Products Co.	Roquette America, Inc.	Tate & Lyle Americas
STARCH PRODUCTS						
Unmodified, food	•	•	•	•	•	•
Unmodified, industrial	•	•	•	•	•	•
Modified, food		•	•	•	•	•
Modified, industrial	•	•	•	•	•	•
Dextrins	•	•	•		•	•
Cyclodextrins					•	
REFINERY PRODUCTS						
Glucose syrups	•	•	•		•	•
Maltodextrins	•	•	•		•	•
Dextrose monohydrate	•	•	•		•	•
Dextrose anhydrous		•	•		•	
High Fructose Corn Syrup-42	•	•	•		•	•
High Fructose Corn Syrup-55	•	•	•		•	•
Crystalline fructose	•					•
CO-PRODUCTS						
Crude oil	•	•	•			
Refined oil	•	•	•			
Corn gluten feed	•	•	•	•	•	•
Corn gluten meal	•	•	•	•	•	•
Corn germ or corn germ meal	•	•	•	•	•	•
Steepwater (CFCE)	•	•	•	•	•	•
Carbon dioxide	•					•
Corn fiber food/industrial ingredients	•	•	•		•	
FERMENTATION AND OTHER CHEMICALS						
Citric acid	•	•				•
Lactic acid	•	•				
Lysine	•					
Threonine	•					
Xanthan gum	•	•				
Erythritol		•	•			
Sorbitol	•	•	•		•	
Xylitol		•	•		•	
Mannitol	•	•	•		•	
Maltitol	•	•	•		•	
Hydrogenated starch hydrolysates			•		•	
Glucose hydrolysates			•		•	
OTHER						
Ethanol, fuel/industrial	•	•		•		•
Ethanol, beverage	•					

Product lists are accurate as of publication date, but may change with time.
Also available online at http://www.corn.org/cra-members/member-products/.

Corn Refining Plant Engineering Technology —Refine, Improve, Optimize

Since the birth of the corn wet milling industry, a number of innovative plant technology developments combined with day-to-day improvements have given the industry greater efficiency and productivity, better working conditions and the ability to provide better products.

During the first 50 years of the industry, most of the engineering developments sought means to save labor inputs, which at the time was the most obvious way to reduce costs. While the industry was still in its infancy, it took more than 20 workers to produce one ton of starch. If this were true today, the industry would require at least 70 million employees.

Three revolutionary changes in plant engineering have resulted in the wet milling industry we now know: the shift from an open-air process to an enclosed process; the change from a process based on gravity to one that employs powered equipment; and the conversion from a system based on processing in batches to a continuous process. These major developments have helped the industry remain one of the fastest growing markets for corn farmers.

The Early Days

During the first half of the 20th century, the corn wet milling process consisted of a series of operations that depended mainly on gravity to effect the separation of the components of the corn kernel.

Flat-bottom wooden tanks filled with corn were covered with a warm solution of water and calcium hydroxide and allowed to set for several days. The soft kernels were then ground in Buhr mills. Germ was separated by flotation in open, U-shaped vats where the germ, floating on the starch suspension was skimmed off the top while the starch and fiber were continuously discharged from the bottom.

The starch and fiber were screened out on open, wooden shakers or reels covered with silk or nylon cloth. The slurry was then transferred to wooden tubs where it was treated with caustic soda and allowed to settle. The water, along with considerable amounts of insoluble starch and gluten from the slurry went to the sewer. Steam and sulfur dioxide permeated the air.

Fresh water was then added to the starch/gluten slurry and transferred to wooden starch tables. The tables were generally about 12 feet wide and 100 feet long with a slight pitch. The slurry flowed in at the higher end and as it moved down the table, the denser starch settled on the table and the lighter gluten and some of the finer starch particles flowed off the end. The surface of the starch was then gently hosed or "squeegeed" to remove the final traces of gluten. Starch was washed either by retabling or by several steps of filtration and re-slurrying, and then drying by a variety of slow methods. The tables took up a lot of space and required tedious manual operations as well as a good deal of cleaning. Gluten was concentrated by settling for two days in large concrete vats then added to the fiber from the shakers and let set for about a week. This gluten/fiber product was then sold to local farmers by the wagon, which they brought themselves.

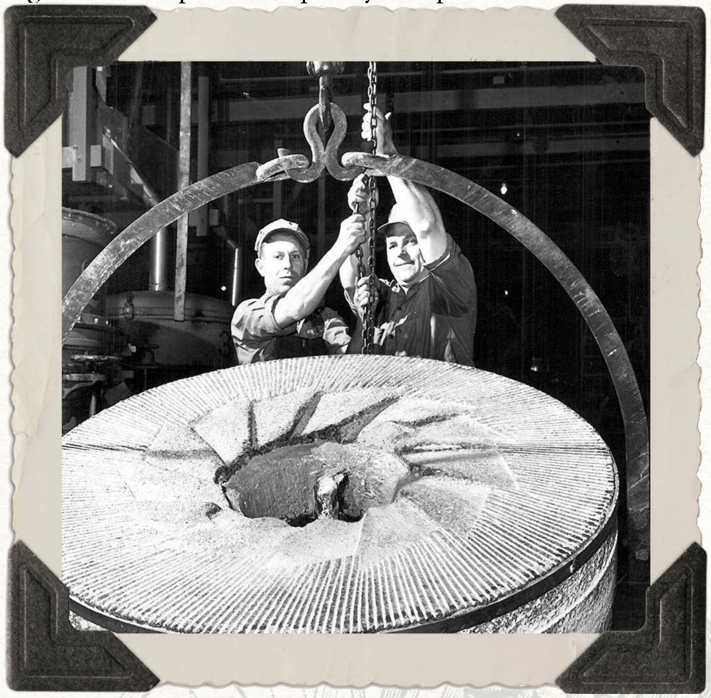
During these early years, the corn refining industry grew and process equipment began to become available from manufacturers who specialized in pumps, filters, screens or dryers. Processing plants gradually grew more numerous and larger in size and more complex in function and in the range of products produced. Looking back, this seems to have been a very slow-paced period. After WW II, developments and changes came rapidly. Equipment suppliers had manufacturing facilities and staff available and the corn refining industry had both capital and expansion opportunities. Thus, new developments and methods were quickly put into place.

During the first half of the 20th century, two significant changes took place. In the mid-20s, efforts to increase yields resulted in the "bottling up" of refining plants. Water from gluten settling tanks, which previously had been dumped into the sewer, was recycled and effluents were reduced. The other major change was the introduction also in the 1920s of rotary vacuum filters for starch and gluten dewatering. The more significant changes occurred in the 1940s and 50s when equipment using centrifugal force was introduced into the various unit operations.

The Post-WW II Era

One of the most dramatic changes was the adoption of centrifuges as replacement for gravity settling tables for separating the starch and gluten. Within a space of about 5 years, every processor had made the change. This revolutionary invention was the idea of Albert Peltzer who had worked as a processor and knew what was needed, and then sought and discovered the answer. Centrifuges provided a cleaner separation of the starch and the gluten, improved the protein content of the gluten and provided a concentrated starch stream with much lower protein content.

The early centrifuges removed only the starch from the gluten. As newer model centrifuges were introduced, eventually the whole process stream was taken through the centrifuge to provide a complete separation of starch and protein fractions. The centrifuge produced high volume separations quickly and proved



to be highly sanitary because of unique design and easy-maintenance features. As centrifuges proved their high performance capability, they began to appear in other unit operations throughout the plant. They eventually replaced the settlers that were used to concentrate gluten and the tables or filters used to wash starch – doing the job in less space and more efficiently.

The use of centrifugal force was revolutionary and the principle was incorporated into other equipment, such as hydrocyclones and screens, as well as in many other configurations of centrifuges. Hydrocyclones took over the separation of germ and replaced the open settling vats with a closed, manifold system that was both sanitary and efficient. The cyclone systems occupy less space and improve germ recovery.

Hydrocyclones were also introduced in the early 50s for starch washing. The countercurrent washing system uses multiples of small diameter cyclones in several concentrating stages. This approach affords the user exceptional process control, as well as such benefits as greater sanitation and washing efficiency. The concentrated starch stream from the primary separation centrifuges passes through several stages of 10 mm cyclone batteries in series. The effect is one of repeated concentration and dilution of the starch stream. The interconnected flow arrangement of the consecutive stages serves to remove the soluble and insoluble protein fractions from the starch.

Economic conditions for corn refiners during the postwar period spurred the introduction of many new mechanical technologies, some of which came out of advances in instrumentation for wartime purposes. Automatic instruments were installed to record and regulate temperatures, pressures, material flows and other process variables. These instruments allowed the arrangement and stabilization of continuous, integrated production sequences, which reduced wastes and product quality variances of the old batch processing system.

It was also during the postwar period that Buhr mills were replaced by impact and attrition mills. Buhr mills were used after the germ was removed to separate the hull and fiber from the rest of the kernel. The Buhr mills required frequent periodic maintenance by skilled stone dressers to restore the grinding surface. The stones were usually good for about five days of continuous operation, but then were out of service for about eight hours to be resurfaced. Impact mills use stationary and rotating pins. Attrition mills employ rotating plates of grooved steel. The new grinding systems required less maintenance and less space.

During the 1960s, bench or DSM screens replaced reels for fiber washing and shakers for germ washing. The DSM screens or "Sievebend" screens were originally developed by the Dutch State Mines for mineral applications. The screens proved to be more compact and efficient than the old reel and shaker systems, not to mention easier to clean and maintain. The screens provided better separation of starch, gluten and fiber fragments and allowed greater starch and gluten recovery.

The Modern Era

During the mid-1970s, the industry saw major changes in design, instrumentation and control systems for plant operation. From 1975 to 1985, 12 new plants were constructed. Old plant designs separated discrete steps of the process in individual buildings, with product being piped from building to building between unit operations. The newer designs kept all major process steps under the same roof, allowing operators to monitor the process from central control rooms and allowing formerly "waste" energy to be recirculated throughout the system.

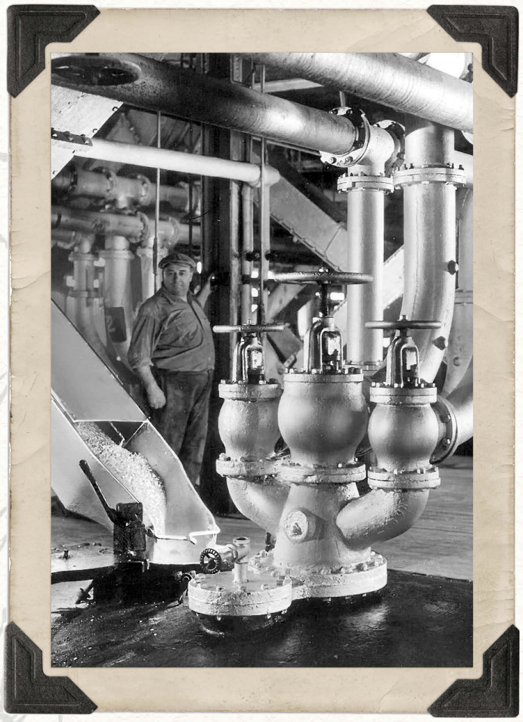
The first "total computer control" plant was the Staley facility built in 1977 in Lafayette, Indiana. Since then, all new plants have been built with central process control computer systems, and computer control has been retrofitted to older plants. Steeping technology saw major improvements in the late 70s changing from a batch process to a continuous process. Prior to this monumental change, batteries of steep tanks holding up to 10,000 bushels of corn had to be filled and emptied. The process took several hours to complete, a lot of energy and several workers. The idea of a continuous steep eluded the industry for quite some time. The problem was how to prevent uneven distribution of fresh corn and steeped corn travelling through the same physical unit.

The solution was found in the angle of the steep tank walls and the height of the tank. The new tanks were designed so the corn could be continuously added to the top with steep and mill water circulating upward through the downflowing corn. The design proved successful and provided nearly the same results as the batch process without the intricate system of valves and pumps. The continuous steep process greatly reduced downtime and labor needs.

At the start of the 1980s, major hardware changes in plants began to occur in the energy production/use area. The industry has adopted a number of innovative boiler designs, and major retrofitting has been done in drying and evaporation systems. Mechanical dewatering and multiple effect, mechanical vapor-recompression evaporators are common retrofits. New plants have been built to take advantage of greatest fuel flexibility, which has required adopting innovative boiler design, both for flexibility and to meet environmental regulations on coal burning. Co-generation facilities have been designed into many new plants and retrofitted to a number of existing plants.

Improvements in membrane materials have greatly expanded the potential application of microfiltration in corn wet mill plants. In the mid-80s, refiners began to employ membrane filtration to remove proteins and other non-syrup materials (called "mud" filtration) from dextrose corn syrup prior to carbon and ion exchange. Membrane filtration improved syrup quality, thereby reducing the carbon usage and extending the life of ion exchange resins. Membranes are also being used to "wash" modified starches and to enrich dextrose streams.

More recently, especially after the introduction of stainless steel membranes, the applications have been expanded to include steepwater filtration, where removal of large molecular weight proteins improves evaporator performance, increases the production of gluten meal and permits high solids concentration of the filtered steepwater for direct sale to fermentation processors. Membranes are also being used to "final filter" finished fructose syrup prior to shipment.



Recent *Developments* in Plant Technology

Today, research on membrane applications, steeping technology and energy efficiency are the focus of the industry. New applications of membranes include gluten thickening, mill stream thickening, starch water clarifying, waste treatment sludge recovery and concentration, yeast recovery and still bottoms concentration.

Trials are being conducted on a steeping process by which corn is milled in stages following short periods of steeping resulting in faster hydration of the kernel and diffusion of sulfite into the endosperm. Tests show yields comparable to those produced through conventional wet milling.

Ways to enhance energy efficiency have always been research goals of the corn refiners and their suppliers. Current research is focused on heat exchangers and boilers.

While the industry can certainly be proud of the achievements already made in wet milling plant technology, the innovative and shrewd nature of those in the industry ensures that there will never be a shortage of ideas on how to improve the process and the products.

Corn Refiners Association Member Companies
Domestic and International Plant Locations

Archer Daniels Midland Company
P.O. Box 1470
Decatur, Illinois 62525

Domestic Plants:
- Decatur, Illinois 62525
- Cedar Rapids, Iowa 52404
- Clinton, Iowa 52732
- Marshall, Minnesota 56258-2744
- Columbus, Nebraska 68601

International Plants:
- Razgrad, Bulgaria
- Guadalajara, Jalisco, Mexico
- Boleraz, Trnava, Slovakia
- Adana, Turkey

Cargill, Incorporated
P.O. Box 5662/MS62
Minneapolis, Minnesota
55440-5662

Domestic Plants:
- Hammond, Indiana 46320-1094
- Cedar Rapids, Iowa 52406-2638
- Eddyville, Iowa 52553-5000
- Fort Dodge, Iowa 50501-8828
- Blair, Nebraska 68008-2649
- Wahpeton, North Dakota 58075
- Dayton, Ohio 45413-8001
- Memphis, Tennessee 38113-0368

International Plants:
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- Song Yuan, China
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- Krefeld, Nordrhein-Westfalen, Germany
- Castelmassa, Veneto, Italy
- Martorell, Barcelona, Spain
- Orhangasi, Bursa, Turkey

Ingredion Incorporated
5 Westbrook Corporate Center
Westchester, Illinois 60154

Domestic Plants:
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- Bedford Park, Illinois 60501-1933
- Indianapolis, Indiana 46221
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- Winston-Salem, North Carolina 27107

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Domestic Plant:
- Cedar Rapids, Iowa 52404-2175

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Tate & Lyle Americas
(A subsidiary of Tate & Lyle, PLC)
P.O. Box 151
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Domestic Plants:
- Decatur, Illinois 62521
- Lafayette, Indiana 47902
- Lafayette, Indiana 47905
- Loudon, Tennessee 37774

International Plants:
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