Minnesota Nutrition Conference
Minnesota Corn Growers Association
Technical Symposium
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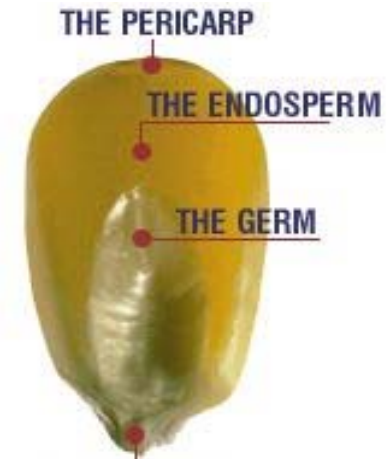
Corn Milling, Processing and Generation of Co-products

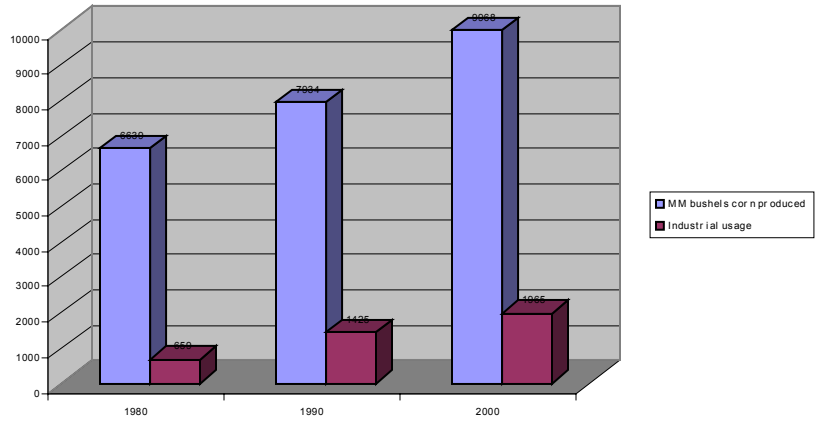
Corn, a distinctive American crop, developed by the Indians, roasted at 4th of July picnics and produced with unparalleled efficiency and dedication by farmers. For every five bushels sold, corn processors buy one bushel to process in to corn syrups, sweeteners, starches, oils, ethanol and animal feeds. These products in turn become the building blocks of thousands of other food and industrial products distributed throughout the world. Eighty percent of all corn grown in the US is fed to livestock, poultry and fish. Nutritional components of yellow dent corn are well known.



Components of Yellow Dent Corn

Starch	61.0 %
Corn Oil	3.8 %
Protein	8.0 %
Fiber	11.2 %
Moisture	16.0 %

Currently in an average year the remaining twenty percent or about two billion bushels of shelled field corn is transported from individual farms by truck, train and barge to industrial corn processing plants. This percentage of "industrial use" versus the amount of corn produced has increased over the decades from 9.9% in 1980 to 17.9% in 1990 to the current 19.7%.



With the new bio-based product initiatives and our need for renewable energy, researchers are looking at corn as a feedstock for other organic chemicals, nutraceuticals and biodegradable polymers and fibers. This will continue the trend of increasing

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percentage of corn grown for industrial processes. Educating nutritionists about the feeding values of these valuable co-products and getting the improved quality data into the new feed formulation programs and literatures is becoming of increased importance.

There are two distinct processes for processing corn, wet-milling and dry-milling and each process generates unique co-products.

The Corn Wet-Milling Process

Wet-milling processing roots are designed based in production of pure starch. Corn wet milling has developed into an industry that seeks optimum use and maximum value from each constituent of the corn kernel. In addition to starch and the other various products, as well as the edible corn oil, the industry has become an important source of well- defined specialized ingredients used in feed formulations. The contents of the different component streams segregated during starch and oil production are recombined and processed to yield products serving specific needs of the feed industry.

Production of feed co-products from corn wet-milling begins with the delivery of shelled corn to the facility. The corn is sampled and quality approved. The corn is off loaded to elevator bins through a cleaning system. From the elevator, the corn is conveyed to large tanks called steep tanks where it is soaked for 30-50 hours at 120 - 130°F in a dilute sulfur dioxide solution. This is a closely controlled process that results in the softening of the corn kernels. During the soaking, soluble nutrients are absorbed in to the water. This water is later evaporated to concentrate these nutrients to become *Condensed Corn Fermented Extractives*. Continuing with the milling process the corn germ is removed from the water soaked kernel. The germ is further processed to recover the oil. The remaining portion of the germ, *Corn Germ Meal* (wet or dried), is collected for feed use. After the germ has been removed, the rest of the corn kernel is screened to remove the bran leaving the starch and gluten protein to pass though the screens. The bran is combined with other co-product streams to produce *Corn Gluten Feed*. This starch and gluten slurry is sent to centrifugal separators, which causes the lighter gluten protein to float to the top and the heavier starch to the bottom. The gluten protein is concentrated and dried to form *Corn Gluten Meal,* a 60% protein feed. Some of the starch is then washed and dried, or modified and dried and marketed to the food, paper and textile industries. The remaining starch can be processed into sweeteners or ethanol.

Wet-milling produces four major co-products for the feed industry from the isolated steep water, bran, germ meal and gluten. Together these co-products represent about 25 – 30% of the corn processed.

Average Yield Per Bushel

Starch	31.5 lbs.
Gluten Feed	12.5 lbs.
Gluten Meal	2.5 lbs.
Corn Oil	1.6 lbs.

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- **Condensed Corn Fermented Extractives** or Corn Steep Liquor is a high-energy liquid feed ingredient. The protein value analyzes at 25% on a 50% solids basis. This product is sometimes combined with the corn gluten feed or may be sold separately as a liquid protein source for beef or dairy rations. It also can be used as a pellet binder and is a source of B-vitamins and minerals.
- **Corn Germ Meal** typically analyzes at 20% protein, 2% fat, and 9.5% fiber. It has an amino acid balance that makes it valuable in poultry and swine rations. It is also used as a carrier of liquid feed nutrients.
- **Corn Gluten Feed** is a medium protein ingredient composed of the bran and fibrous portions. It may or may not contain the condensed corn extractives. This product is also sold as wet or dry. The bran and condensed extractives (sometimes germ meal) are combined and dried in a rotary dryer. The dried corn gluten feed is made into pellets to facilitate handling. It analyzes typically as 21% protein, 2.5% fat, and 8% fiber. Wet corn gluten feed (45% dry matter) is similarly combined but not dried. It is a perishable product in 6 –10 days and must be fed or stored in an anaerobic environment. These feeds are widely used in complete feeds for dairy and beef cattle, poultry, swine and pet foods.
- **Corn Gluten Meal** is a high protein concentrate typically supplied at a 60% protein, 2.5% fat and 1% fiber. It is a valuable source of methionine. Corn gluten meal also has a level of xanthophylls, which offers the poultry feed formulators an efficient yellow pigmenting ingredient. Corn gluten meal also is an excellent cattle feed providing a high level of rumen bypass protein.

The Corn Dry-Milling Process

The beverage ethyl alcohol distilling industry in the late 19th century pioneered the recovery of the nutrients from grains, which had undergone fermentation. It was immediately recognized as an excellent source of dairy cattle feed. Ethyl Alcohol was a critical item during WWII for the manufacturing of munitions. The beverage alcohol industry was asked to meet the demand. Obviously, cereal grains were an important commodity for livestock feed as well as human food and it was necessary to recover these nutrients remaining after the fermentation process. The world oil crisis in the 1970's and recent clean air legislation have contributed to an expanded dry-mill industry. Currently legislative issues are before Congress that could triple the demand for ethanol as an oxygenate component in gasoline. This increased ethanol demand will likely come from the dry-milling of corn thereby offering an increased amount of co-products.

Shelled corn arrives at the facility and is accepted through quality check procedures. The mashing and fermentation of the corn is mechanically simple but from a chemical and biological process are quite complex. The corn is cleaned of foreign materials and hammer milled to a medium-coarse to fine grind meal. This corn meal is then mixed with fresh and recycled waters in known ratios to form a slurry. The pH (5-6 pH) and temperature (180 -195°F) is adjusted and an alpha amylase enzyme is added to facilitate the hydrolysis of the cornstarch to dextrin (long chain sugars). This process step is referred to as liquefaction. After complete liquefaction of the starch the mash is "cooked" to kill unwanted lactic acid producing contaminating bacteria. The mash is

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then cooled to 90°F and sent to a fermentation vessel where a glucoamylase enzyme is added that converts the dextrin into the simple sugar dextrose. Yeast species, *Saccharomyces cerevisiae*, are used to metabolically convert the dextrose in to ethanol and carbon dioxide. The fermenting mash is referred to as a "beer". The corn protein and recycled waters (stillage) provide a major source of nitrogen compounds absorbed by the yeast microbes. The fats and fiber in the fermenter remain untouched and concentrate as the starch is converted to ethanol. Fermentation is completed in 40- 60 hours. The beer is then sent to the distillation area to strip away the ethanol. The water and all solids (protein, fat and fiber) are collected from the distillation base and referred to as whole stillage. This whole stillage is then centrifuged to separate the coarse solids from the liquid. The liquid is referred to as thin stillage, which is recycled to the beginning of the process or concentrated in the evaporator to become *Corn Condensed Distillers Solubles*. The coarse solids collected from the centrifuge are called wetcake. Wetcake and condensed solubles are then combined and dried in a rotary dryer to form the feed co-product *Corn Distillers Dried Grains with Solubles*.

Average Yield Per Bushel

Ethanol	2.7	gallons
DDGS	18	lbs.
CO_2	18	lbs.

- **Corn Condensed Distillers Solubles** (CDS) is a term generally used to refer to the evaporated co-products of the grain fermentation industry. Most of the CDS is added to the dried grains but some is available as a liquid feed ingredient. The quality and composition of CDS can be affected by a number of factors including the original substrate, the process used, and evaporation procedures. Nutritional properties of this product can vary greatly. On a dry matter basis CDS typically is 29% protein, 9% fat and 4% fiber. The solubles are an excellent source of vitamins and minerals, including phosphorous and potassium. CDS can be dried to 5% moisture and marketed but generally the dry matter content is between 25 – 50%. In addition to its nutritive qualities, it has also proven to be a highly palatable feedstuff, which can effectively be used to boost consumption of other feed ingredients. CDS is a brown, free flowing to semi-solid liquid similar in viscosity to molasses. Because of the fermentation of the sugars, it is less sweet than molasses, and the taste ranges from neutral too slightly sour. Because of its nutritive composition and high palatability, CDS can be a valuable addition to many livestock rations, especially those requiring high nutrient density or those diets which include ingredients which animals may find less acceptable such as

poorer quality roughages. Like other feedstuffs, it performs best as a component of a properly balanced ration.

- **Corn Distillers Dried Grains with Solubles** (DDGS) are recovered in the distillery and contain all the nutrients from the incoming corn less the starch. Thus the DDGS has at least three fold as much nutrients as the incoming grain. Approximately 4% of the amino acid in corn is broken down and then reconverted to the more nutritionally valuable microbial types. Since the stillage is recycled, the ratio of these more valuable amino acid types continues to increase so that eventually they represent approximately 16% of the final DDGS's amino acid content. No other feed ingredient (corn gluten feed or meal, soybean meal, etc) results from such a great percentage of microbial products and their back stocking. The yeast also provides increased vitamins, particularly the B-complex group. DDGS typically analyzes as 27% protein, 11% fat and 9% fiber. DDGS provides ruminants with an excellent source of bypass protein. This product is also available in a wet form. DDGS has been successfully included in rations for beef and dairy cattle, poultry, swine, aquaculture and pet foods.

The corn plant is an efficient factory for converting large amounts of radiant energy from the sun into a stable form of chemical energy stored as cellulose, oil and starch. It has proven to be a very versatile grain. The end products produced from corn are used in our everyday life. As we expand the processing of corn by investing in research that looks for more value added components or harvest the crop to produce expanded quantities of renewable liquid transportation fuels we will also generate more quantities of excellent co-products for the feed industry.

Acknowledgments: National Corn Growers Association and Corn Refiners Association

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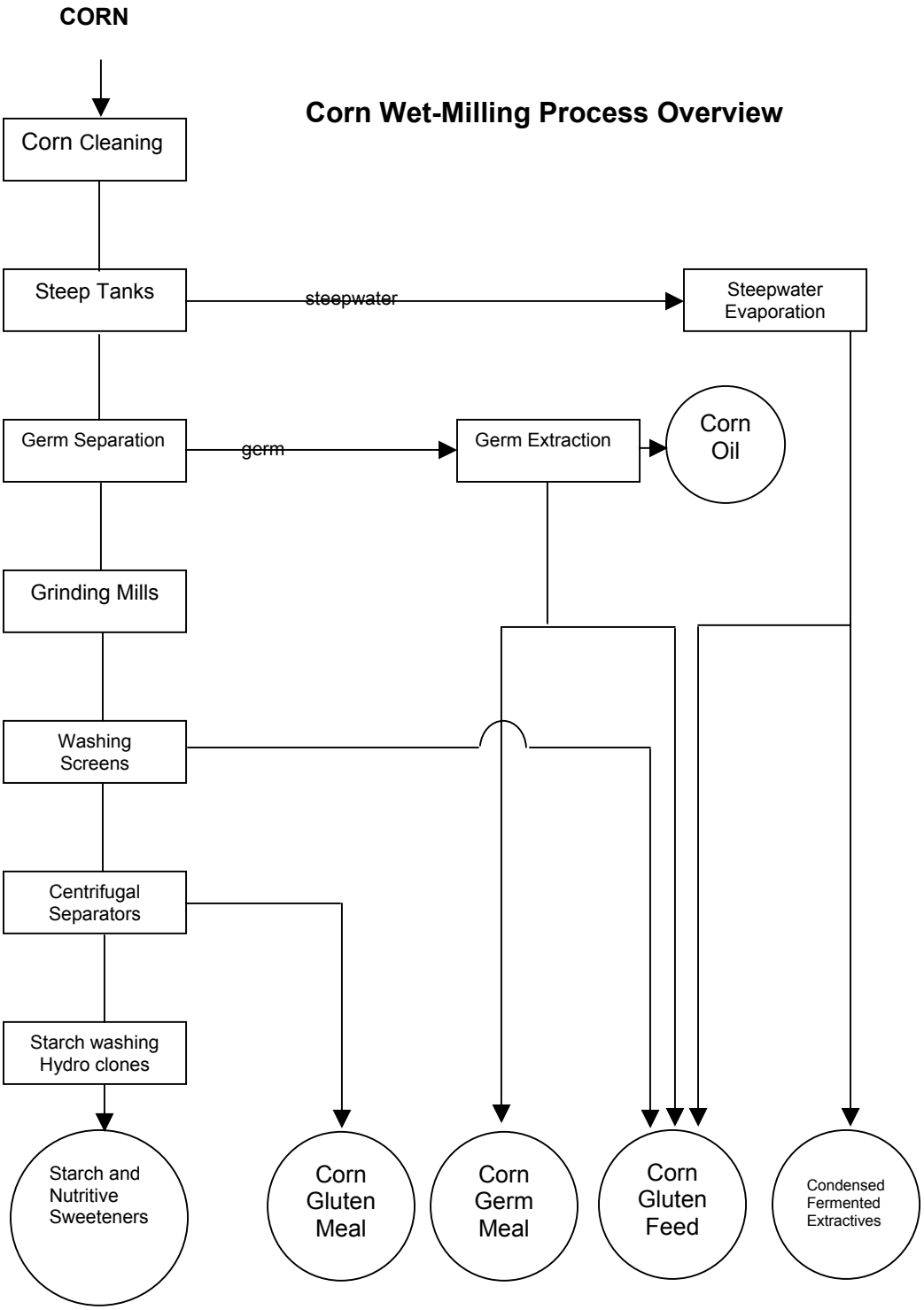

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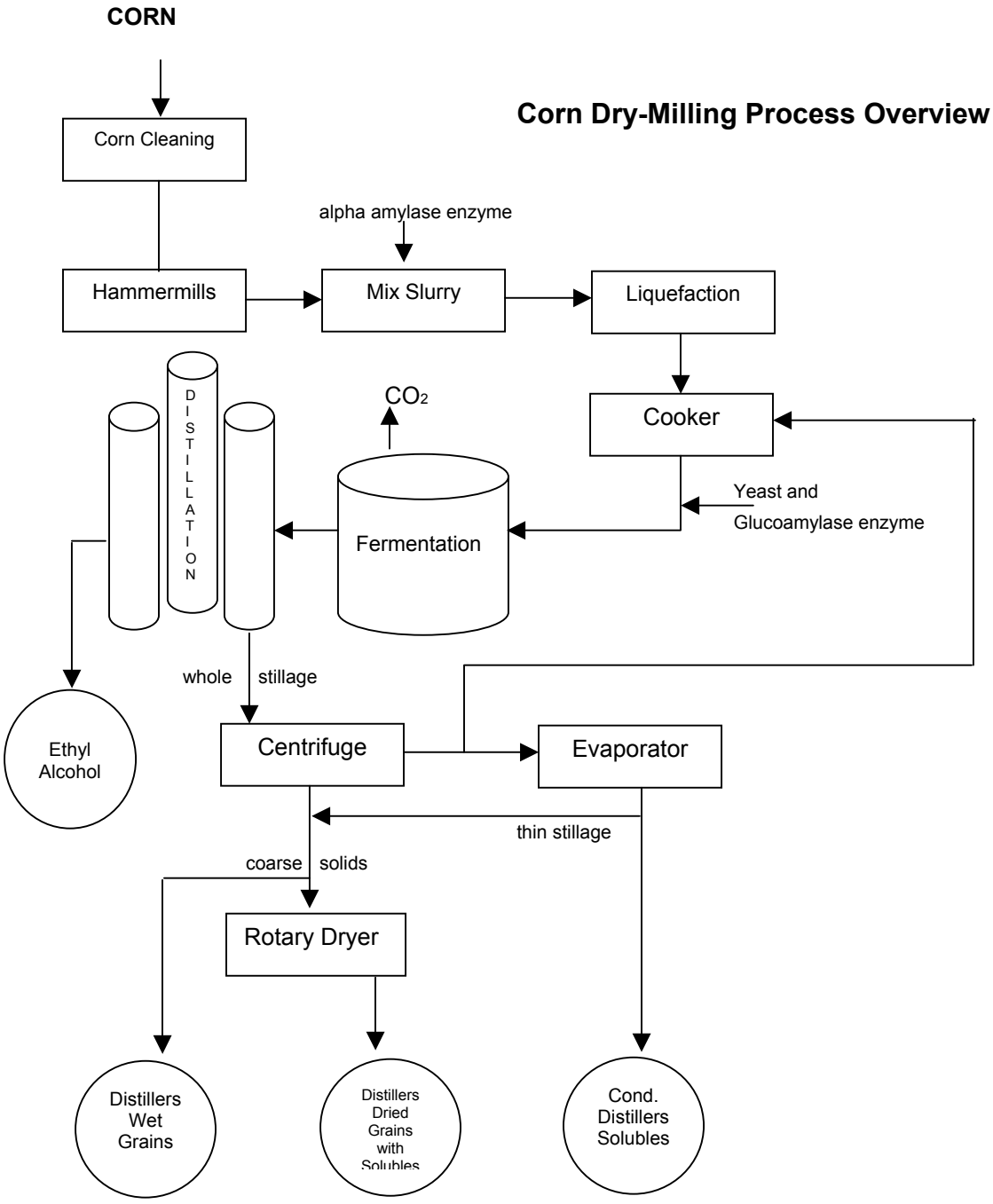

Feed Industry Co-products

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