



SNS COLLEGE OF TECHNOLOGY
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Unit 1 – Topic 4

Corn – Wet and Dry Milling

Introduction

Corn or Maize (*Zea mays*, L) is used for animal feeding, for human consumption and for the manufacture of starch, corn syrup solids, sugar, beer, industrial spirit, etc. The products of milling include maize grits, meal, flour, and protein and corn steep liquor. Corn is consumed as human food in many forms. In its harvested wet form, it is consumed as vegetable. The ready-to-eat breakfast cereal ◆corn flakes◆ is made from maize grits. Popcorn ◆ the first snack food is undoubtedly the oldest snack food. The majority of corn consumed as human food has undergone milling and is consumed as a specific or modified fraction of the original cereal grain. Like other cereal grains, corn is milled to remove hulls and germ.

6.2 Corn Classification

Maize or corn is classified commercially into four main classes as follows:

1. Dent varieties, which, when mature have a pronounced depression or dent at the top of the kernel. These have hard patches of densely packed endosperm cells at the outer edges of their endosperm and soft, opaque cells toward their center. Their shapes vary from long and narrow to wide and shallow.
2. Flint varieties, which have a continuous hard layer surrounding the endosperm. When these kernels dry, they dry evenly and therefore do not form a dent.
3. Flour or soft varieties, which are almost entirely opaque and soft. It is the soft maize varieties that are normally used to make corn flour.
4. Waxy maize varieties that have a waxy appearance especially when broken. The starch consists of very little amylose and is effectively 100% amylopectin (maize starch is normally about 30% amylose and 70% amylopectin).

6.3 Corn Processing

Maize is processed by dry or wet milling. Dry milling may or may not include de-germing as a preliminary step. Non-de-germing dry milling is carried out on a local basis in small grist mills or in modern roller mills using sifters and purifiers. The maize is ground to make coarse wholemeal of 85 ◆ 95% extraction rate. This wholemeal is highly susceptible to the rancidity as the germ is retained which has a high oil content. Wet milling and dry milling involving de-germing are carried out in large commercial mills.



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Corn wet-milling is a process of breaking corn kernels into their component parts: corn oil, protein, corn starch, and fiber. It uses water and a series of steps to separate the parts to be used for various products.

History

The corn wet-milling industry has been a primary component of American manufacturing for more than 150 years. Corn refiners established the process of separating corn kernels into their component parts to produce a variety of value-added products. The four main component such as oil, protein, starch, and fiber are the primary product from the corn wet-milling process. The Associated Manufacturers of Products from Corn was formed in 1913 when the group of corn refining companies' industry successfully grew.

Description

Corn wet-milling is a process where components of corn kernels are extracted to produce a highly purified product. Most of the products from this process are valuable and mainly required by the food industry. Through this process, every part of the corn is useful to produce the quality ingredients. The characteristics of this process are based on physical separation of components, mostly by weight and size. Water is needed as it is a wet process and it works as separation/carrier agents in washing steps. Therefore, this process can be considered as having high capital cost. The only chemical use in this process is aqueous sulfur dioxide solution, which is used in the steeping process. The corn is soaked in this solution to soften the kernel so that the oil in the germ will not contaminate other products and is easy to separate.

Process steps

Cleaning

As per the standards of the U.S. Department of Agriculture, Grade 5 is usually used for wet-milling. Harvested corn has to be cleaned before it is milled. Dockage tester with appropriate sieve number is used to removes particles other than the required grain like cob pieces, foreign seeds, metal pieces, leaves, dirt and the percentage of dockage contained can be calculated. The cleaned corn is then analyzed for its composition using an NIR spectrometer. The compositional analysis of yellow dent corn carried out at the Center for Crops Utilization Research, Iowa State University, is recorded in the table below.

NIR Compositional Properties					
Moisture (in %)	Protein (in %, dry basis)	Oil (in %, db)	Starch (in %, db)	Density (in g/cc)	Test Weight (in lb/bu)
13.8	8.93	4.29	70.4	1.282	65.6



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Steeping

In this process, the corn is hydrated in order to loosen starch granules from the protein matrix while leaving the germ resilient to milling. This process reduces the germ density and softens the kernel, making the milling easy. Chemicals like sulphur dioxide and lactic acid are also added to the water. Lactic acid breaks down the endosperm protein matrix and helps in better separation of starch. It also lowers the pH, preventing growth of microbes. SO₂ reacts with the disulphide bonds and weakens the matrix, allowing starch granules to separate out cleanly. It also serves as an anti-microbial. At the end of steeping, the protein matrix is weakened, endosperm proteins are solubilized and some soluble solids diffuse out into the steepwater. The clean corn is steeped in large tanks with water at 125-130°F containing lactic acid and sulphur dioxide for nearly 40 hours. The steepwater is then drained using appropriately sized mesh screens and concentrated using multiple effect evaporators. Use of concentrated steepwater: This extract is protein-rich and can be used as nutrient media for fermentation to produce enzymes or antibodies. It is also used in animal feed.

Germ recovery

As the process step suggests, in this step the germ is separated from the other parts of the corn. Recovering the germ as intact as possible is necessary to prevent any oil contamination in the final products. Attrition mills such as disk mills are used to coarsely grind the softened corn kernels. The grinding is slow and the elements used to grind are blunt to ensure intact removal of germ. Water is added to the ground material to make a thick slurry of macerated kernels and whole germ. The 40-50% crude oil content of germ makes it less dense than other particles and as a result germ floats in the mixture. The mixture is then passed through germ hydrocyclones with an over- and underflow. Overflow will be composed majorly of germ and water and underflow will have fiber, starch, protein and water. The overflow is passed through the hydrocyclone multiple times since 100% separation cannot be achieved in a single pass. The separated germ is cleaned, dried and passed through a germ press to extract oil from it. Solvent extraction can also be used alternatively. The solid particles remaining after oil extraction is called germ meal which is further dried.

Germ meal is a good source of amino acids and is a carrier of micro-ingredients in animal food formulations. The refined corn oil can be used as salad oil and cooking oil. It is also used to prepare corn oil margarines.

Fiber recovery

The underflow from the hydrocyclone consisting of fiber, protein and starch is finely ground and screened using multiple grind mills and pressure-fed screens. Screens are used to separate the fiber from the mixture. Various screen sizes are used to remove coarse and fine fibers. A wedge bar or profile bar screen is used. Starch and protein passes through the screen and collected whereas the fibers remain on the screen and it is called corn gluten feed. The principle



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of separation is difference in size. The corn gluten feed has approximately 21% protein, 1% fat and 10% fiber and 15% starch. Since it is high in water-soluble nutrients, it is used as one of the main ingredients in animal feed. It can also be used to produce refined corn fiber to be used for human consumption.

Protein recovery

The slurry containing just the protein and starch is called millstarch. Water is removed from the millstarch in a thickener before moving it into a separator. Centrifugal forces are applied to separate starch and gluten which differ in density. The heavier starch slurry is then washed multiple times in hydrocyclones with fresh water. The starch stream typically has 90% starch and the gluten stream consists of 60% protein. The lighter gluten, separated out from the top, is thickened and the heavy gluten is further sent for dewatering into vacuum rotary filter. This corn gluten meal consist of approximately 60% protein, 1% fat and 3% fiber. The process water from both the processes are either added to steepwater or removed. Since it has around 60% protein, it is used as animal feed and zein products.

Starch processing

Starch goes through multiple-stage washing using hydrocyclones. The supernatants are separated at each washing stage. The water from each stage is recycled to the previous hydrocyclones to ensure the maximum amount of starch is separated. A very high purity of starch (>99.5% db) can be recovered by wet-milling. Purity is important when the end product is high-fructose corn syrup or starch to be modified (using chemicals or enzymes) but it is not important during ethanol production. After centrifugation and washing, the starch is dried.

Co-product manufacture

Co-products account for 34% of wet-milled yield. In fact, 23% of corn that is processed has very low or no value. The fiber, concentrated steepwater and germ meal are mixed to produce corn gluten feed. As mentioned before, corn gluten meal is also used as animal feed. Although both have 'gluten' in the name, no gluten protein is present in them – there is none in corn on whole.

A typical solid yield (on db) data for yellow dent corn is shown in the table below.

Fraction	Yield on dry basis (in %)
Starch	58-68
Gluten Meal	5.8-15.4



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Fiber (coarse+fine)	8.8-19.2
Germ	5.2-10.5
Steepwater solubles	5.1-7.5
Total solids recovery	97.3-99.9

Primary products

The wet-milling process will have five major products: steep water solids, germ, fiber, starch, and gluten. However, the co-product from this process will produce corn oil, corn gluten meal, corn germ meal, corn gluten and feed steep water. The average of one bushel of corn generally will have about 32 lb of starch or 33 lb sweeteners or 2.5 gallons of fuel ethanol and 11.4 lb gluten feed and 3 lb gluten meal and 1.6 lb corn oil.

6.3.1 Dry milling

- Two different systems are used for dry milling of corn.
- The non-degerming system grinds corn into mill with hardly any separation of germ. This corn meal has comparatively shorter shelf-life, as the germ is retained, which contains 32 ♦ 35% oil. This oil in presence of oxygen and lipolytic enzymes is prone to oxidative and hydrolytic rancidity.
- Hence, it is necessary to remove the germ from corn to produce corn products with much lower fat content and greater shelf-life.
- Tempering and degerming system remove most of the germ and hull and leave the endosperm as free of oil and fiber as possible to recover maximum yield of endosperm and germ as large clean particles.
- Corn is cleaned to remove dirt, stones, insects, tramp iron, broken kernels and extraneous plant materials.
- The corn is then conditioned by adding water to increase the moisture content to 20%, and the moistened corn is allowed to equilibrate for 1 ♦ 3 hrs. The objective of conditioning is to loosen the germ and toughen the bran and to mellow the endosperm so as to obtain a maximum yield of grits and a minimum yield of flour in the subsequent milling.
- Degerming and dehulling is carried out in one of the three ways:
 1. Beall de-germinator (De-germer and corn huller)



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2. With roller mills and sifters
 3. With impact machines such as entoleters and gravity separators
- Once the germ and hull are removed, the endosperm is reduced in size to grits with roller mills. A complex array of additional roller mills and particle size separating equipments is used to purify and size endosperm particles. All products must be dried prior to packaging or bulk storage.