Correct Terminology Usage in Corn Processing

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Terminology in any business is important for the clarity of communication among scientists, engineers, and managers. Confusion in terminology can lead to wasted time, the frustration of personnel, and ultimately the loss of revenue. The common usage of terms should be readily definable and specific to its application. The corn processing industries of wet milling, dry milling, and dry grinding have several areas where popular terms are confusing. This article attempts to clarify the correct usage of terms and in some cases the definition of terms.

Kernel Composition

The first area needing clarification is corn kernel composition. There is much confusion regarding the different components of fiber and protein in the kernel and where each component ends up in the different processes. Corn has four main components: the pericarp, the endosperm, the germ, and the tip cap.

Pericarp

The pericarp is the outer coating of the corn that is often called the "hull" or "bran," both of which are inappropriate terms. Peanuts have hulls, but only one phenotype of corn (pod corn) has a hull. A hull is a separate entity encapsulating the kernel but that is not directly attached to the kernel. Bran is a term referring to the outer layers of the wheat kernel and is not a botanical term but a coproduct or fractional term (7). The preferred term is pericarp, a continuous semipermiable barrier to diffusion that is attached to the outer most layer of the germ and endosperm, covering all but the tip cap. It is semipermiable in that very small molecules such as water (MW = 18) can diffuse through it but even slightly larger molecules of sulfur dioxide (MW = 64) cannot. The pericarp is primarily composed of hemicellulose (branched polymers of 5- and 6-carbon sugars in alpha-glycosidic bonds) and cellulose (an unbranched polymer of 6-carbon sugar in beta-glycosidic bonds), with some addition of waxes and oils (11). The pericarp is more than 91% fiber and because corn is low in water-soluble fiber, fiber can be closely approximated by the neutral detergent fiber (NDF) analysis. Any pericarp sample containing less than 91% NDF has probably been diluted by attached endosperm.

There are three sources of fiber in the corn kernel: the pericarp, which contains approximately 51% of the kernel's fiber; endosperm cell wall fiber (referred to as cellular fiber), which contains approximately 32% of the fiber; and germ cellular fiber, which constitutes the balance of the fiber. The term coarse fiber can be used for pericarp to distinguish it from cell wall fiber found in the endosperm. In the past, the term "fine fiber" has been used for cell wall fiber. Coarse fiber was recovered separately in the reels and the fine fiber was recovered in the shakers. However, today, the industry uses bent screens and recovers the fiber as a combined fiber. The term fine fiber has come to mean the fiber that passes through the 50-micron bent screens and ends up in the starch sample (if it doesn't plug up the starch washing hydrocyclones first). To avoid confusion, the preferred term for the endosperm fiber is "endosperm cell wall fiber." The germ cell wall fiber is not recovered in the fiber stream of any process because the germ contains the oil and the cell wall that are needed to keep the oil together until pressed or extracted. None of the processes recovers the fiber from the germ separate from the germ. Extracted germ meal is high in NDF (approximately 58%), but this is much lower than the 91% of corn pericarp.

Endosperm

The endosperm is composed of starch that is encapsulated in a protein matrix inside of cells. There are two types of endosperm: "hard" or "vitreous" endosperm and "soft" or "opaque" endosperm. These are the preferred terms for the two types of endosperm. The difference between the two is visual as well as structural. The hard endosperm has a higher density, more protein, more tightly packed protein than soft endosperm, and looks translucent. It is also more yellowish in color in yellow dent corn. White dent genotypes lack the yellow carotenoids. Soft endosperm is not highly packed, and the protein matrix collapses during drying, so there is no semblance of order in this part of the endosperm. There are other terms for the hard and soft endosperm that are appropriate, including "translucent" and "horny" as terms for hard endosperm and "corneous" and "floury" as terms for soft endosperm. What is not appropriate is to use the terms "gluten" for hard endosperm and "starch" for soft endosperm. Gluten is a mixture of very specific wheat proteins (gliadin and glutinin). It's the proteins that form a complex elastic matrix that entrap CO_2 in the bread dough, resulting in the bread expanding and rising. It is not a corn protein, nor is gluten a generic term for protein.

The storage protein in the corn endosperm is known as glutelin and is classically defined as an alkali-soluble protein although there are now known to be many subclassifications (5). Another protein found in corn endosperm is zein, a prolamin (due to its high content of the amino acid proline) that is soluble in 70% ethanol.

Germ

The germ is the living part of the kernel and as such contains the necessary enzymes, energy, and nutrients to build roots and shoots. The term "germ" often conveys the idea of a bacterial infection, so it is probably best to use the term "embryo" instead. However, the term germ is widely accepted and does not lead to ambiguity.

Most of the nonstorage protein in the corn germ is water or salt soluble (known as albumins and globulins, respectively). Albumins and globulins have more diverse amino acid profiles and are biologically active as enzymes which expedite the conversion of starch to sugars and other short-chain carbohydrates in order to provide energy to the germinating embryo. There are also some endogenous proteases that help break down the endosperm protein matrix and endogenous lipases that help break down triacylglyerides.

doi:10.1094/CFW-55-3-0144

Tip Cap

The “tip cap” is the part of the kernel that was attached to the cob and through which all of the building block molecules, nutrients, and water are delivered to the kernel. The tip cap is the smallest of the corn components; yet, it is a vital entryway into the kernel. As the corn matures and dry down initiates (dry down is the removal of moisture from the corn kernels back down through the cob and stalk), a black layer or hilar layer forms in the tip cap in an attempt to seal it.

Corn Fractionation Processes

There are four basic methods used to industrially process corn: wet milling, dry milling, dry grinding for ethanol fermentation, and nixtamalizing (Figure 1). The “nixtamalization” process (also known as the “masa” process or “alkali” process) is for making tortillas and tomales, etc., and, while it is a fast-growing segment of the corn market, it is a small percentage of total corn utilization. Other various direct processes to make fermentation products, gruels, and porridges are not considered in this classification scheme because we are focusing on the U.S. market.

Wet milling is the process of fractionating the corn kernel through grinding in the presence of water and chemicals and/or enzymes via steeping to release the starch from the endosperm protein matrix. The primary goal is to produce starch in a high yield that is as pure as possible from protein, fat, and fiber. Most wet-milled starch is used for food or industrial products and only a small percentage is fermented to ethanol. There are a number of different specific wet-milling processes available, including intermittent milling, dynamic steeping (6), e-milling (4), alkali wet milling (1), and a modified Westfalia process (2). However, almost all commercial wet mills use the standard counter-current steeping process. Wet milling is not just any process that mills the corn after hydration of the kernels. For example, the nixtamalization process, when the corn is cooked at 90°C in a lime solution, steeped back to ambient temperatures, stone ground and then made into tortillas, is not a wet milling process because the process objective is not to fractionate the kernel into starch and other fractions. Similarly, hydrating kernels and then milling them to release the germ is not a wet-milling process because the kernels were not steeped.

Steeping distinguishes wet milling from other potential processes that hydrate the kernel with water only. It is a process in which the kernels are subjected to hydration in the presence of a reducing agent that acts on the protein matrix of the endosperm to weaken the inter- and intra-peptide disulfide bonds and achieves some measure of starch release. Alternatively, the protein matrix can be broken down with proteases. Steeping is normally done counter currently with fresh corn coming into the process at the front end and sulfur dioxide-laced process water entering at the other end and transported upstream to contact the fresh corn. Steeping can be done with a number of different chemicals or enzymes (although it is more effective to enzyme treat postgrinding because the pericarp resists diffusion), at different temperatures, in batch or continuous, or for different lengths of time. Steeping is used to describe the tempering process that occurs when alkali-cooked corn is allowed to cool to ambient conditions. This is the correct use of the term “steeping,” even though this process is not a wet-milling operation because the objective is not the separation of starch from the corn.

Terminology problems in wet milling exist because of the naming of two of the coproducts: corn gluten meal and corn gluten feed. Again, corn does not contain any gluten because gluten is specific to wheat. Because of the pervasive use of the “gluten meal” and “gluten feed” terminology, it will be difficult to change. One acceptable alternative designation could be “corn glutelin”

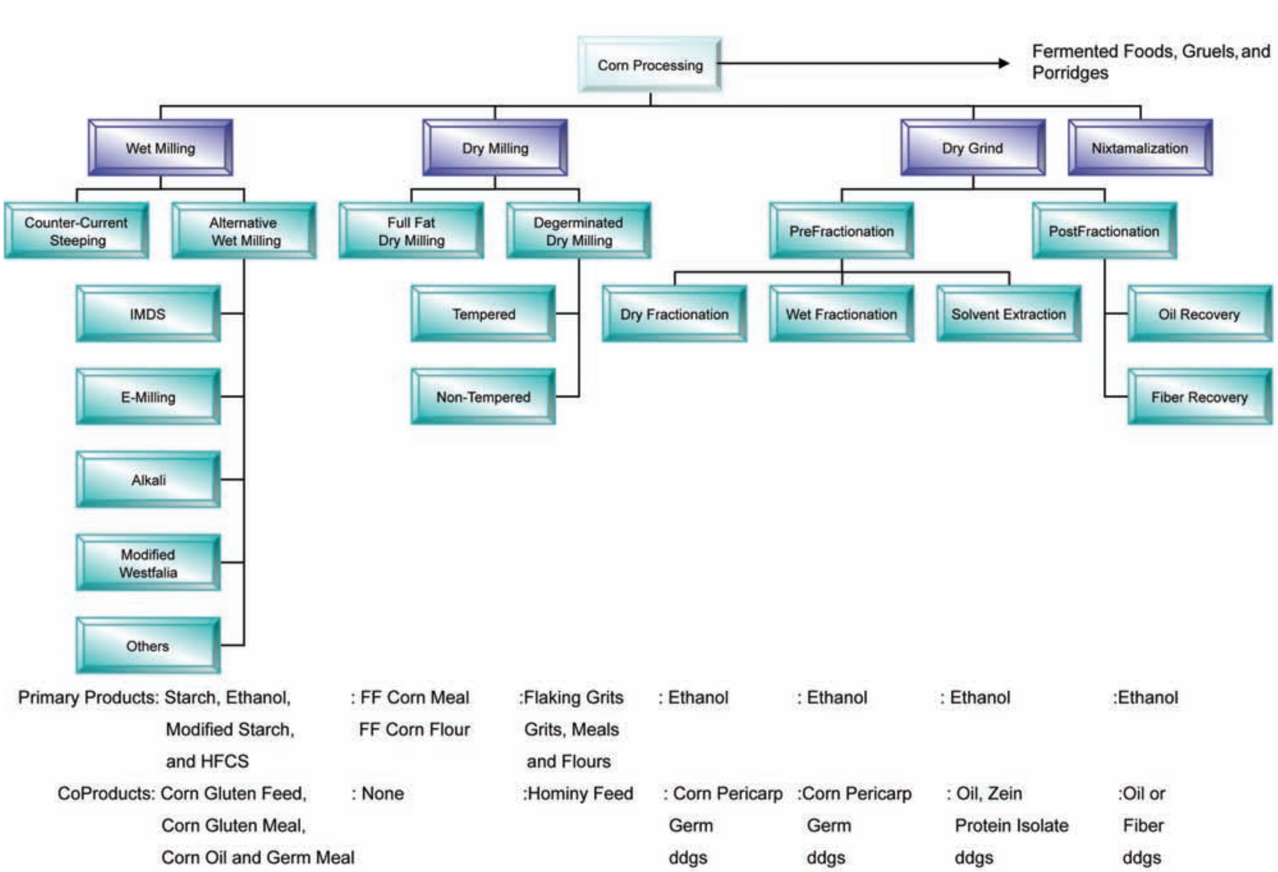

Fig. 1. Nomenclature for major corn processes.

meal or feed. This designation does not appreciably change the tempo of the names but is more accurate.

Corn dry milling is the process of fractionating the corn kernel to recover endosperm pieces (grits, meals, and flours, differentiated by particle size) with minimal contamination of germ or pericarp. High contents of germ in dry-milled fractions can lead to a short shelf life due to lipid oxidation. Usually, high yields of flaking grits for the breakfast cereal industry are preferred because flaking grits command higher prices than smaller particle-sized fractions. The recovery of a high percentage of germ and pericarp comes with a significant loss of endosperm. Water can be used in dry milling if it is used to preferentially hydrate certain parts of the kernel to enhance germ and pericarp separation. This process of using water to create these moisture gradients is called tempering.

Throughout history, there have been three processes that have been referred to as "dry milling." The first and oldest process is the full-fat dry-milling process where corn is stone ground or ground using metal roller mills to a meal or flour consistency. No separation of components occurs and technically it should be called "full-fat dry grinding" or "unbolted dry milling." The objective is to delineate it from "degerminated dry milling" (described above) and the "dry-grind" process, so any of these terminologies achieves the objective.

Dry-Grind Ethanol Process

The "dry-grind ethanol" process is the conventional process for producing ethanol in which the corn kernels are ground with a roller or hammer mill to reduce particle size prior to being cooked and converted to ethanol. In much of the older literature, the dry-grinding process is referred to as dry milling, and the term is still used by some today. However, within the last 15 years, some process developments have muddied the classifications. In order to recover valuable coproducts, pre- and postfermentation fractionation procedures have been developed for dry-grind ethanol facilities. The objective of prefractionation is to recover the germ and pericarp with as little loss of endosperm starch as possible prior to fermentation so that carbohydrate levels can be increased and stirring horsepower reduced. Dry fractionation uses dry-milling equipment in simplified approaches to remove the germ and pericarp. These fractionation approaches are usually far simpler than those used in dry milling because the size of the endosperm particles is not a factor (smaller particles are even preferred). The processing approach differs from dry milling in that the objective is to maximize germ and fiber recovery with minimal loss of carbohydrate. Dry milling attempts to remove all the germ and fiber, accepting higher losses of carbohydrate than dry fractionation (25 versus 4%). Primarily, dry fractionation uses some form of conventional degerminator followed by aspirating and sieving.

Wet fractionation uses a soaking step followed by standard wet-milling operations to recover the germ and pericarp (8,10). Although the coproducts of wet and dry fractionation are labeled similarly, they are compositionally very different. Wet fractionation results in a wet-milling type germ and fiber with a higher oil content germ (35–45% versus 18–25%) that also has lower residual starch and larger pericarp pieces. Dry fractionation looses at least 4% of the fermentable carbohydrate compared to less than 2.0% lost by wet fractionation.

A third group of prefractionation processes are those that utilize solvent extraction of protein and oil before the residual is fermented to ethanol (for example, the sequential extraction process [SEP]) (3). There has been limited interest in these processes during the current expansion of ethanol due to the high capital costs associated with them and the lack of market.

Postfractionation tries to separate out oil from the distiller's dried grains with solubles (DDGS) using pressing, flotation, centrifugation, and solvent extraction. Postfractionation avoids the loss of starch associated with prefractionation but does not gain the advantages of removing the nonfermentables from the fermenter. Also, the fermentation has a negative and undesirable effect on the quality of oil recovered and generally is not acceptable for human consumption but can be used for adding energy to feeds or for manufacturing biodiesel. Fiber recovery using the elusieve process (9) attempts to decrease the fiber content and increase the protein content of the DDGS so it can be used at higher levels in nonruminant animals. The protein content of DDGS increased by 8% using the process.

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