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Corn Quality for Industrial Uses

Characteristics of corn used by industry are discussed here.

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Publications frequently refer to the term "Corn Quality," but this term means little without being placed in context.

The Official U.S. Standards for Grain defines Corn Quality for typical marketing transactions involving grain marketed in the United States. It rates corn quality based on purity, color, the amount of broken and foreign material, total numbers of damaged kernels (including heat-damaged, sprouted, frosted, weather or ground damaged, moldy, diseased), heat-damaged kernels, stones, moisture, and test weight. Official standards, however, are only useful as general indicators of grain quality.

Grain quality is best defined as a measure of the suitability of a grain for its intended use. The highest quality corn for a cattle feeder would be the corn that promotes maximum healthy weight gain. High quality corn for making starch is the corn that gives the greatest yield of starch for the starch producer.

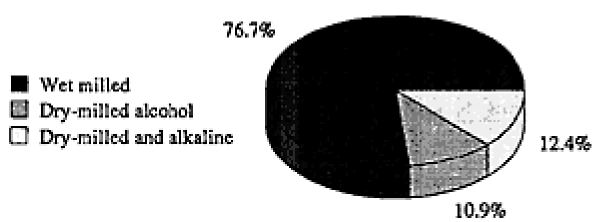

Figure 1. Corn used for food and other industrial purposes -- 1.3 billion bushels yearly.

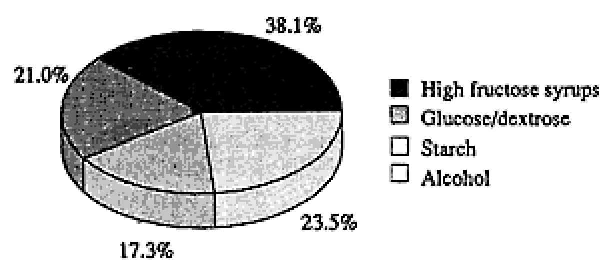

Figure 2. Amount of corn used for starch and starch-derived chemicals (wet milling) -- 998

A high quality corn for a particular use is not necessarily a high quality corn for a different use. A high quality corn for starch production might be a low quality corn for snack production, and vice versa.

million bushels yearly.

Industrial Uses for Corn

While used primarily for feed, over 1.3 billion bushels of corn are used for food, alcohol and other industrial uses (*Figure 1*). The corn is primarily used by three distinct industries that have different needs and expectations for their corn.

Corn Wet Milling

Corn wet milling is a complex industrial process. Most larger wet millers process approximately 100,000 bushels of corn daily, and the primary product is starch and starch derived chemicals (*Figure 2*). Oil, bran and protein also are obtained in wet milling. Oil is further processed to produce various salad oils and similar products. Protein and bran are used primarily as feed ingredients. Additional processing produces modified starches, maltodextrins (slightly degraded starch), sweeteners, alcohol, and other chemicals/pharmaceuticals derived from fermentations.

Corn is soaked in large tanks with small amounts of sulfurous acid derived from sulfur dioxide gas; lactic acid bacteria growing in the steep water also produce small amounts of lactic acid. These two chemicals, in water held at 122°F, help soften the corn kernel over a 24-48 hour steeping period. After steeping, the corn is coarsely ground.

The ground corn and some steep water is sent to a hydrocyclone, which essentially allows the germs, or the lightweight oil-containing portion, to float to the top of the mixture and be removed. The fibrous material is screened off, and the starch and protein (often after additional milling) are separated by density using large banks of centrifuge-like equipment. The starch fraction subsequently can be processed to improve its use in food and industrial products.

For example, starch can be chemically modified to resist changes when stored in a refrigerator (i.e. the formation of water seen on top of a starch-based pudding), or starches can be treated with natural proteins (enzymes) to produce high-fructose corn sweeteners found in soft drinks. In addition, starch can be fermented to produce alcohol.

Starch is routinely used as an adhesive, for manufacture of papers, and as a filler for pharmaceuticals. Starch, pending further additional research and improved marketing, theoretically can be converted into an enormous assortment of industrial chemicals now produced from petroleum sources. Wet milling also produces many by-products used as high-quality animal feed. The wet milling industry is the largest non-feed user of corn, using approximately 1 billion bushels annually.

Corn Dry Milling and Alkaline Cooking

Corn dry-milling is essentially a simple grinding procedure. Corn is cleaned, then the moisture content is raised to 20 percent. The germs are removed for oil extraction, and the remaining corn is ground and sieved into many fractions varying in particle size and composition. The primary products are flour, cornmeal and grits (ground corn with a particle size larger than typical cornmeal). Other products include corn bran, corn oil, and feed mixtures. These products are used in brewing, foods (breakfast cereals, snacks, baked goods, etc.), building products (binders), fermentations (pharmaceuticals and fuel), and animal feeds.

Dry milling for alcohol production uses approximately 161 million bushels (alcohol produced by the wet-milling industry accounts for 306 million bushels of corn).

Alkaline-cooked corn is used to produce tortillas, tortilla chips, corn chips and similar items (taco shells, etc.). Whole kernel corn is cooked in near-boiling water with 1 percent lime (based on corn weight) for approximately 20 minutes, then the corn is allowed to soak for 8-12 hours. After steeping, the corn is drained from the steep water and washed with clean water to remove loose pericarp (hull) and excess lime.

The washed corn, now at approximately 45-50 percent moisture, is then stone ground to form a dough. If the dough is immediately formed into strips and fried, the resulting product is a corn chip. If the dough is formed into thin pancake-like sheets and baked, a corn tortilla results. If the baked tortillas are subsequently fried, a tortilla chip results.

Dry-milling (for food use) and alkaline cooking together use 142 million bushels of corn annually.

Corn Marketing

Because of current corn marketing practices, corn's primary use as an animal feed, and a feed-based grain grading system, corn types purchased by industry sometimes are not optimized for their processes. Since the marketing system is not geared to providing "optimized" hybrids, nor has research reached the point that such hybrids can be easily and readily identified, some processors are unwilling to expend the time and expense associated with identifying a particular hybrid, geographic region and producer to contract for such corn.

To expand and maintain foreign and domestic corn markets, producers and processors must become more aware of the opportunities for production and purchase of corn with optimized processing and shipping characteristics.

Corn Characteristics

Corn hybrids with different genetic backgrounds, or grown under different conditions or different farming practices, result in corn that also exhibits different kernel characteristics. These unique kernel characteristics result in corn that can be better or less suited for a particular end use.

Corn quality research has resulted in increasing our knowledge about what characteristics are best suited for industrial uses. Unfortunately, our ability to predict which corn will have optimum suitability for wet milling, dry milling or alkaline cooking is far from perfect. Additional research in this area is needed.

There are, however, general kernel traits that indicate suitability for particular end uses.

Corn for Wet Milling

Unfortunately, perhaps because of the complexity of the process, there are few readily identifiable corn traits that directly relate to increased starch yield. Many chemical and physical corn quality tests fail to adequately predict the performance of particular corn hybrids. The only clear corn kernel characteristics that result in higher yields of starch for wet millers are large kernels that are softer (i.e., more "floury") in texture.

Softer kernels probably result in higher starch yields because the starch is less tightly "cemented"

together (by protein) within the kernel, so it is easier to separate from the protein and other kernel components. Kernel softness and size, however, only explain 40-50 percent of the observed differences between hybrids seen when this corn is wet milled. That means the kernel characteristics that help predict wet milling yields are largely unknown. A rapid method is being tested at the University of Nebraska-Lincoln to help predict the wet milling yield of corn; this technique uses a single instrument to characterize numerous chemical and physical traits at once. While an easy method to predict wet-milling quality has yet to be fully developed, there are clear differences in wet milling yields found between corn hybrids, and within a single hybrid grown under different environmental and cultural practices.

These differences, however, are currently only readily identifiable when laboratory-scale wet milling is performed. Further research efforts in this area are necessary.

Corn for Dry Milling

Corn characteristics ideally suited for dry milling are more readily identifiable. Approximately 80 percent of the differences in dry milling product yields between hybrids can be associated with particular kernel traits. The best dry-milling corn has larger-sized kernels, low kernel size variability, harder kernel texture, and higher protein contents. Harder type dent corns, or flint corns are best suited for dry milling. Harder corn is desired because when a kernel is dry milled it does not easily break (or crumble) like a soft textured corn. This results in larger yields of the highest value product: flaking grits.

Flaking grits are composed of nearly whole kernels of corn (minus the germ or oil fraction) that can subsequently be used to produce corn flakes. The larger the single piece of unbroken corn, the larger (and more desirable) the flake. Breakfast cereal manufacturers pay a premium for this dry-milled fraction.

Corn for Alkaline Cooking

Characteristics for the best alkaline-cooked corn also are easily identified. Again, approximately 70 percent of the differences in alkaline cooking yields between hybrids can be associated with particular kernel traits. Snack food and tortilla manufacturers want the highest possible yields of masa. They want low amounts of solids in the cook water (which most dispose into the local sewer system, often at a premium price), and they want a readily removed pericarp (outer kernel surface or "hull"). They also want corn that is not susceptible to overcooking. This translates into wanting corn which, when cooked, takes up moisture slowly.

The advantage of a slower-cooking corn is that operator error or equipment failure, which results in longer cooking or steeping times, only slightly affects masa quality.

Corn that yields greater amounts of masa and is less susceptible to overcooking typically is that with larger-sized kernels and low size variability, hard (but not brittle), a lower starch content, and pericarp ("hull") that is difficult to remove. Of course, since pericarp removal is a desirable property, a reasonable balance must be struck between the easy machinability afforded by corn that has easy to remove pericarp and the resulting simultaneous loss of masa yield. The most desirable corn might be that with a very thin and easy to remove pericarp.

Corn for alkaline cooking also must have some additional characteristics. Specifically, it is best for it to be from a white cob. Red cob pieces, which inevitably get into the product, are seen as red specks and considered a defect. Also, corn color is important. Depending upon the geographic region, and the particular product being made, white corn or white/yellow corn mixes are used to produce a lighter color

product.

Summary

Over 1.3 billion bushels of corn are used yearly for human food and other industrial purposes. The market, and market potential, for these uses are growing each year.

Because corn is composed of a convenient food for microorganisms (starch), these microorganisms can be used to produce many pharmaceutical and industrial chemicals, all derived from corn. In addition, starches can be converted using non-microbial chemical techniques to produce a wide assortment of other chemicals. Eliminating barriers to further development of additional markets for corn depend upon politics, research to develop new products, and research to industrialize and scale-up laboratory processes.

New processes using corn must be economically competitive with "traditional" manufacturing, and efforts must be placed into developing business ventures to market these corn-based products. Corn has significant advantages over traditional sources of industrial chemicals in that it is a domestically available renewable resource.

Just as corn hybrids have been developed that are "genetically customized" to yield best in particular growing regions, it also must be recognized that to expand markets, corn must be "genetically customized" for its eventual use, whether it be for feed or industrial use, whether intended for domestic or foreign markets. Research to find out what corn properties are most desirable for particular end uses is just beginning.

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