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IPG Lab Corn Test Information

Food Grade Corn Test Bundles

Basic Food Grade Bundle

This bundle of tests evaluates those characteristics which have traditionally been most important to food-grade corn handlers and users.

These include:

- NIR Proximate Analysis
- Thins
- % Horneous Endosperm
- Density, 100 Kernel Weight and Average Kernel Volume
- Test Weight

Alkaline Cooker Bundle

The alkaline cooking process is used to make corn chips, corn tortillas, and corn tortilla chips. This bundle includes the tests that are important to the Alkaline Cooking industry.

Tests included are:

- Pericarp Removal
- Moisture Uptake during Cooking
- Visual Kernel Characteristics

This bundle, in addition with the Basic Food Grade Bundle is helpful to be placed on alkaline cooking companies' approved hybrid lists.

Dry Millers Bundle

Corn Dry Millers physically separate corn into grits, flour, and meal.

Tests included are:

- Germ-to-Endosperm Percentage (Grit-to-Germ Ratio)
- Extended Kernel Sizing (22/64, 20/64, 18/64, 16/64 round screens)

This bundle, in addition with the Basic Food Grade Bundle is helpful to be placed on dry milling companies' approved hybrid lists.

Physical Characteristics

Stress Crack Analysis

Stress cracks are internal fissures in the hard endosperm of a corn kernel. The pericarp of the kernel is not damaged, so the outward appearance of the kernel may be unaffected at first glance.

The cause of stress cracks is pressure buildup due to large gradients of moisture content and temperature within the kernel's hard endosperm. The internal stresses are not able to build up as much in the soft, floury endosperm. A kernel may have one, two, or multiple cracks. High-temperature drying is the most common cause of stress cracks. Therefore, high levels of stress cracking can serve as a guide to poor suitability for particular uses.

Wet Milling – larger amounts of broken corn lost in cleaning (screening to remove chaff, broken grain and small kernels), lower starch yield due to high-temperature drying.

Dry Milling – larger amounts of broken corn lost to cleanout, lower yield of the most valuable products (large grits).

Alkaline Cooking – larger amounts of broken corn lost in cleaning, disturbance of process balance leading to overcooking or undercooking.

The IPG Lab evaluates stress cracks using a backlit viewing board to accentuate the cracks. Two replicates of 100 intact kernels (no external damage) are examined. The severity of the stress crack damage is related to the total number of stress-cracked kernels and the number of cracks in each kernel. Many corn users will specify the acceptable level of cracks.

The Stress Cracks Test report includes:

- % Stress Cracks – Percentage of kernels with at least one crack
- % Single Stress Cracks (SSC) – Percentage of kernels with only one crack
- % Double Stress Cracks (DSC) – Percentage of kernels with exactly two cracks
- % Multiple Stress Cracks (MSC) – Percentage of kernels with more than two cracks
- Stress Crack Index (SCI) – Weighted average, showing severity of cracking
  - SCI is calculated using the formula: ***SCI = [SSC x 1] + [DSC x 3] + [MSC x 5]***

Lower numbers for the percentages and index are always better. If stress cracks are present, singles are better than doubles or multiples. Many contracts are written with a stress crack allowance of 20%, but this may vary from case to case.

% Stress Cracks	Possible Values 0-100%	Typical Results 0-60%
% Single Stress Cracks	Possible Values 0-100%	Typical Results 0-30%
% Double Stress Cracks	Possible Values 0-100%	Typical Results 0-20%
% Multiple Stress Cracks	Possible Values 0-100%	Typical Results 0-50%
Stress Crack Index	Possible Values 0-500	Typical Results 0-300

On November 29, 1995, the Grain Inspection, Packers, and Stockyards Administration (GIPSA) published in the Federal Register (60 FR 61194) a final rule offering stress crack testing of corn effective January 1, 1996. The method developed at the Identity Preserved Grain Laboratory was selected as the official GIPSA method for stress crack analysis.

Germ-to-Endosperm Percentage (Grit-to-Germ Ratio)

The Grit-to-Germ Ratio is also offered as a component of the **Dry Millers Bundle**.

This test relates the amount of grit (endosperm) in the kernel to the amount of germ (embryo). This is useful to all food corn users, but especially dry millers. Dry millers process the kernel to physically separate the bran (pericarp) and germ from the endosperm to produce grits. Larger grit pieces are more valuable. The germ can be processed for oil, which is also a valuable product, but incomplete separation of germ from the grit pieces greatly reduces the grit quality. Hence, the desire is for more grit and less germ in the kernel.

In this test, kernels are soaked approximately 48 hours to soften the kernel. Twenty kernels are hand-dissected to remove the pericarp and then the germ. The germ and endosperm pieces are dried, and the percentage of the germ weight to the weight of the grit is reported on a dry basis. A lower percentage of germ is typically preferred by food corn users.

Possible Values 8.5-14.5%   Typical Results 10-12%

Thins Test

The Thins Test is also offered as a component of the **Basic Food Grade Bundle**.

Kernel size is very important to all food grade corn users. Small kernels will result in excessive cleanout losses. It is difficult for dry millers to make large grits from small kernels. Variability in kernel size will affect the consistency of the alkaline cooking process. The Thins test provides a good estimate of the average kernel size of a sample.

The test is performed by screening 250 grams of corn over a 20/64" round-hole screen. The corn passing through the screen is collected and weighed.

Thins are calculated using the equation: ***% Thins = (Weight of material in pan /* 250 g**) **x 100**

The desired Thins percentage will vary by user, though nearly all would prefer less than 50%.

Possible Values 0-100%   Typical Results 5-75%

% Horneous Endosperm

The % Horneous Endosperm Test is also offered as a component of the **Basic Food Grade Bundle**.

This test provides a measure of endosperm hardness to alkaline cookers and dry millers.

The test is performed by visually rating the kernels, placed germ facing up, on a light table. Soft endosperm is opaque, and will block light. Hard, or horneous, endosperm is translucent. A rating is made from standard guidelines based on the degree to which the soft endosperm at the crown of the kernel extends down toward the germ. Ratings for twenty externally sound kernels are averaged for the reported result.

Most food grade corn users prefer a result of 90% or higher for the % Horneous Endosperm Test, although some may accept as low as 85%.

Possible Values 70-100%   Typical Results 70-95%

True Density

The True Density Test is also offered as a component of the **Basic Food Grade Bundle**.

This test provides a measure of endosperm hardness to alkaline cookers and dry millers.

Density is calculated by dividing the weight of a sample of 100 externally sound kernels by the volume of the same 100 kernels. The weight is obtained using an analytical balance with a minimum of four decimal places. The volume is determined using a helium pycnometer. Two-100 kernel replicates are averaged.

The density (in grams per cubic centimeter), 100 kernel weight (in grams), and average kernel volume (in cubic centimeters) are reported. Because true density will decrease as moisture content increases, the moisture content of the sample is also reported. It is recommended that the sample be between 12 and 16% moisture for analysis. Most food grade corn users want densities higher than 1.31 grams per cubic centimeter.

100 Kernel Weight	Possible Values 15-50 grams	Typical Results 25-40 grams
Average Kernel Volume	Possible Values 15-35 cm^3	Typical Results 20-28 cm^3
True Density	Possible Values 1.17-1.37 g/cm^3	Typical Results 1.25-1.35 g/cm^3

Test Weight

Test Weight, or bulk density, is also offered as a component of the **Basic Food Grade Bundle**.

Test Weight is a measure of the quantity of grain required to fill a specific volume (Winchester bushel). There is often, though not always, a strong correlation between Test Weight and True Density. As such, Test Weight is often used as a gauge of endosperm hardness to alkaline cookers and dry millers. High-test weight corn will take less storage space than corn with a lower test weight. Test Weight is a part of the GIPSA Official United States Standards for Grain grading criteria.

The test involves filling a test cup of known volume through a funnel held at a specific height above the test cup to the point where grain begins to pour over the sides of the test cup. A strike-off stick is used to level the grain in the test cup, and the grain remaining in the cup is weighed. The weight is then converted to and reported in the tradition U.S. unit, pounds per bushel (lb/bu). Because Test Weight can decrease as moisture content increases, the moisture content of the sample is also reported. It is recommended that the sample be between 12 and 16% moisture for analysis. Most food grade corn users desire Test Weights higher than 60 lb/bu with some requesting a minimum of 62 lb/bu.

Possible Values 48-67 lb/bu	Typical Result 56-64 lb/bu

Pericarp Removal Index

The Pericarp Removal Index is also offered as a component of the **Alkaline Cooker Bundle**.

The alkali cooking process is used for making products such as corn tortillas, tortilla chips, and corn chips. Corn is simmered in a dilute lime (calcium hydroxide) solution. The lime dissolves the pericarp to varying degrees based on the composition of the pericarp. Water is absorbed by the kernel during cooking.

The test involves adding samples of corn to a gently boiling 1% lime solution and simmering for 20 minutes. After the cook time is complete the sample is immediately rinsed with tap water to cease the cooking process and rinse any dissolved pericarp from the cooked grain (nixtamal). The sample is drained and stained using a dye that will color the remaining pericarp material selectively for easier rating. Individual kernel ratings are made on a scale from 1 (complete removal) to 5 (essentially no removal). Individual kernel ratings are averaged for the final reported result.

Snack food makers would like complete removal of the pericarp. Excess pericarp in the nixtamal can lead to expensive process disruptions and also to discolored product. They prefer results of 1-3. Tortilla makers can accept more pericarp in their product. In fact, the cooked pericarp will act to help the tortilla have a longer shelf-life by retaining moisture, increasing pliability (softness) of the tortilla, and reducing the need for artificial additives. Values from 2-4 are desired.

Some corn kernels will have a dark bronze color or red streaks in the pericarp (outer kernel coat). During alkaline cooking, the red pigments react with the calcium hydroxide, turning a dark green – almost black – color. In addition, the reaction binds the dark pericarp to the endosperm. This results in undesirable dark specks in the product.

Possible Values 1-5 Typical Results 1-4

Moisture Uptake During Cooking

The Moisture Uptake Test is also offered as a component of the **Alkaline Cooker Bundle**.

The Moisture Uptake Test evaluates the ability of the grain to absorb water during the alkaline cooking process. Process stability is critical to a manufacturer. Fewer adjustments to keep the process within its design parameters result in production of a more consistent product. Moisture content of the corn after cooking is a critical process parameter. The Moisture Uptake Test allows the cooking characteristics of corn samples to be compared. Processors prefer that the corn they use have consistent cooking characteristics.

Corn samples are placed in a 1% lime (calcium hydroxide) solution at room temperature and rapidly heated to 100°C followed by 25 minutes of cooking at a gentle boil. The samples are immediately removed, cooled, and drained to remove exterior moisture. The moisture content is determined on the sample using the Air Oven method. This final moisture content after cooking is reported as the Moisture Uptake.

Possible Values 30-50% Typical Results 35-45%

Visual Kernel Characteristics

The Visual Kernel Characteristic Ratings are also offered as a component of the **Alkaline Cooker Bundle**.

The Visual Kernel Characteristics scores are available individually or as a group of five tests. Twenty individual kernel ratings are averaged to determine the final result.

There are certain visible characteristics that can convey a great deal about a corn sample's suitability for food grade corn uses.

Crown Score – The Crown Score is a measure of kernel hardness. It is a rating of the amount of opaque soft endosperm that is deposited at the crown (see picture) of the kernel. Ratings of individual kernels are made on a scale of 1 (soft endosperm extends half or more of the length of the kernel from the crown) to 9 (no soft endosperm visible at the crown). A rating of 6 (soft endosperm at the crown extends to, but not over, the "shoulders" of the kernel) or higher is preferred by most processors, but will vary.

Possible Values 1-9 Typical Results 4-8.5

Dent Score – The Dent Score is another measure of kernel hardness. As corn kernels mature, soft endosperm at the crown compresses while the hard endosperm remains rigid. This results in a dimple, or “dent”, in the crown. This is reason for the term “dent corn”. Nearly all corn grown in the U.S. is of the dent corn type. Softer corn has a deeper dent. Ratings of individual kernels are made on a scale of 1 (very deep dent with wrinkling of the crown and potential “kissing” as the edges of the dent are pulled to each other) to 9 (no dent). A rating of 6 (the dent is still more of a smooth-edged depression than an abrupt cavity in the crown) or higher is preferred by most processors, but will vary.

Possible Values 1-9   Typical Results 4-8.5

Split Kernel Horneous Endosperm – The Split Kernel Horneous Endosperm Score is yet another measure of hardness. The hard endosperm in corn is preferentially deposited in specific locations within the kernel. The first hard endosperm is laid down on the “back” side (opposite the germ face) of the kernel. As kernels get harder the quantity of hard endosperm at this location increases to a point where hard endosperm begins to be deposited on the germ side (between the germ and the crown) in increasingly larger amounts. This phenomenon is easily observed by splitting a kernel in half through the germ face. Ratings of individual kernels are made on a scale of 1 (no hard endosperm visible) to 9 (very large deposit of hard endosperm between the crown and germ face). A rating of 6 (hard endosperm is just beginning to be deposited on the germ side of the kernel) or higher is preferred by most processors, but will vary.

Possible Values 1-9   Typical Results 3-8.5

Color Rating – The Color Rating is a measurement of the color of the grain. The color of the raw material can dramatically affect product color. Individual kernels are rated by comparison to color standards. The scale for yellow corn goes from 1 (dark bronze) to 8 (bright yellow). The scale for white corn goes from 1 (light yellow) to 8 (bright white). Most processors desire ratings of 5-6 (light orange for yellow corn, or slightly off-white for white corn) or higher. Cutoffs will vary by user.

The dark reddish-brown color is usually in the pericarp (outer kernel coat). On occasion, the endosperm may be the source of the darker orange color. During alkaline cooking, the red pigments in the pericarp react with the calcium hydroxide, turning a dark green – almost black – color. In addition, the reaction binds the dark pericarp to the endosperm. This results in poor pericarp removal index ratings and undesirable dark specks in the product.

Possible Values 1-8   Typical Results 3-7.5

Kernel Red Streaks Rating – The red streaks seen on some kernels are the same pigments that cause the overall bronze discoloration described in the Color Rating section above. Red streaking is due to a combination of genetic and environmental causes, but the dynamics are not fully understood. Some red streaks are caused by a chemical secreted by the wheat curl mite (*Aceria tulipae*). The streaks will often occur nearer the tip of the ear, and usually near the tip cap, although they can occur any where on the kernel. Another type of red streaks can be induced by peeling back the husks of maturing susceptible corn plants. Certain hybrids and inbreds are more susceptible than others. Some nearly always streaked, some never show streaks, and some are completely unpredictable for the occurrence of red streaks. White corn generally shows less red streaking than most yellow hybrids.

Ratings of individual kernels are made on a scale of 1 (complete coloration of the kernel) to 8 (no red streaks). A rating of 7.8 (four out of twenty kernels may have very slight red specks) or higher is preferred by most processors, but will vary. Some processors may eliminate consideration of a sample with any red streaking.

Possible Values 1-8   Typical Results 3-8

Broken Corn & Foreign Material (BCFM)

Broken Corn & Foreign Material is part of the GIPSA Official United States Standards for Grain grading criteria. Higher levels of BCFM will indicate that a sample may have been through more, or rougher, handling than another sample with lower BCFM. Higher levels of BCFM lead to decreased storability and can be a dust explosion hazard.

This test determines the amount of all matter that passed through a 12/64 inch round-hole sieve and all matter other than corn that remains on the top of the sieve. The IPG Lab is not an officially designated grain inspection facility, and, therefore, cannot issue official grades. The data from the IPG Lab can be useful in making decisions, but cooperative arrangements can also be made with the local official inspection station in the case that official documentation is required. BCFM is reported as a percentage of the initial sample.

Possible Values 0-20+%   Typical Results 0-5%

Whole Kernels / Cracked & Broken

The exterior integrity of the corn kernel is very important to alkaline cookers. Any nicks or cracks in the kernel will allow water to enter the kernel much faster than in an intact one. Too much water uptake during cooking can result in expensive process shutdown time or a product that does not meet specifications for quality and composition. No company can afford to have these occur at a high frequency. Some companies even pay extra premiums, over and above contracted premiums, for corn delivered above a specified level of whole kernels. While hard endosperm texture lends itself to preservation of more whole kernels than does soft corn, the primary factor in delivering whole kernels is handling during and after harvest. The type of conveyance (bucket elevators are better than screw augers), number and length of conveyances, and even combine configuration will have a profound effect on kernel integrity.

In the Whole Kernels Test, 50 grams of cleaned (BCFM-free) corn is inspected kernel-by-kernel. Cracked, broken, or chipped grain, along with any kernels showing significant pericarp damage are removed, the whole kernels are weighed, and the result is reported as a percentage of the original 50 gram sample. Some companies perform the same test, but report the “Cracked & Broken” percentage. A Whole Kernels score of 97% equates to a Cracked & Broken rating of 3%.

Possible Values 0-100%   Typical Results 0-20%

Total Damage

Total Damage is part of the GIPSA Official United States Standards for Grain grading criteria. This test determines the amount of damaged kernels from various reasons such as mold, insects, heat, ground, sprout, or cob rot. Most of these types of damage result in some sort of discoloration or change in kernel texture. It does not include broken pieces of grain that are otherwise normal in appearance. The IPG Lab is not an officially designated grain inspection facility, and, therefore, can not issue official grades. The data from the IPG Lab can be useful in making decisions, but cooperative arrangements can also be made with the local official inspection station in the case that official documentation is required.

A representative working sample of corn is visually examined by a proper-trained individual for content of damaged kernels. Damage is reported as the weight percentage of the working sample that is damaged grain.

Possible Values 0-15+%   Typical Results 0-5%

Class

A corn sample will belong to one of the three classes of corn – yellow, white or mixed. This test is part of the GIPSA Official United States Standards for Grain grading criteria. The kernels from a 250 gram sample are separated by color. Class is defined by the following criteria:

Yellow Corn - Yellow kerneled and contains not more than 5.0 % of corn of other colors.

White Corn – White kerneled and contains not more than 2.0 % of corn of other colors.

Mixed Corn – Corn that does not meet the requirements for the other classes and includes white capped Yellow corn.

The result is reported as Yellow, White, or Mixed. The IPG Lab is not an officially designated grain inspection facility, and, therefore, can not issue official grades. The data from the IPG Lab can be useful in making decisions, but cooperative arrangements can also be made with the local official inspection station in the case that official documentation is required.

Chemical Components

NIR Proximate Analysis - Corn

NIR Proximate Analysis is also offered as a component of the **Basic Food Grade Bundle**, and NIR Extractable Starch.

Proximates are the major components of the grain. For corn, the NIR Proximate Analysis includes Oil Content, Protein Content, Starch Content (or Total Starch), and Moisture Content. The test does not include Fiber Content or Ash Content. This procedure is nondestructive to the corn. Proximate Analysis is also available using wet chemistry methods for protein content, oil content, and moisture content but the sample must be ground.

Various end users have different demands for grain composition. A hog feeder may want increased oil and protein levels to increase feeding efficiency. A dry-grind ethanol manufacturer may want more starch, since that should increase his product yields.

Results (other than Moisture Content) are reported on a dry basis percentage (percent of non-water material). Moisture Content is reported "as is" (percent of total sample weight).

Oil Content	Possible Values 2-20+%	Typical Results 3-8%
Protein Content	Possible Values 5-20+%	Typical Results 6-16%
Starch Content	Possible Values 50-80%	Typical Results 62-75%
Moisture Content	Possible Values 5-35%	Typical Results 8-17%

NIR Extractable Starch

NIR Extractable Starch provides a prediction of the yield of starch in a corn sample from the wet milling process. This procedure is nondestructive to the corn. The calibration was developed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign using the 100 Gram Wet Milling test as the reference method.

The primary purpose of wet milling is to efficiently separate kernel components to obtain starch. Some hybrids contain more starch than others. Differences in the grain can affect the amount of Total Starch in the corn sample that is recovered in the wet milling process as starch product. The remaining unrecovered starch goes into lower-value feed products. So, even in samples containing the same amount of Total Starch, one sample may yield considerably more starch product after milling than another.

The starch recovery is the amount of starch product (predicted starch yield or extractable starch content) divided by the total starch present in the sample. This number can serve as a guideline to the millability, or efficiency of separation, of the sample.

The NIR Extractable Starch test report includes the Extractable Starch Content (predicted starch yield), NIR Proximate Analysis – Corn, and the Predicted Starch Recovery. Extractable Starch is reported on a dry basis percentage.

NIR Extractable Starch	Possible Values 45-72%	Typical Results 60-70%
Predicted Starch Recovery	Possible Values 60-100%	Typical Results 85-95%

Amino Acid Profile – Corn

Amino Acid Profile is available using wet chemistry (HPLC) methods.

The Amino Acid Profile provides an analysis of the amino acid content of a corn sample. Amino acids are the "building blocks" of protein. The proper blend of amino acids (a measure of protein quality) is necessary for a proper feed ration. Amino acids must be supplemented if the diet is insufficient or negative productivity or health consequences will develop.

In this test, a ground sample of corn is analyzed using a NIR spectrophotometer. The instrument uses a calibration to evaluate the level of 15 individual amino acids:

Cystine	Possible Values	0.10-0.30%	Typical Results	0.15-.023%
Methionine	Possible Values	0.10-0.30%	Typical Results	0.15-0.34%
Lysine	Possible Values	0.20-0.40%	Typical Results	0.24-0.33%
Threonine	Possible Values	0.25-0.50%	Typical Results	0.29-0.43%
Tryptophan	Possible Values	0.07-0.09%	Typical Results	0.07-0.09%
Arginine	Possible Values	0.30-0.60%	Typical Results	0.37-0.54%
Valine	Possible Values	0.30-0.60%	Typical Results	0.33-0.54%
Serine	Possible Values	0.25-0.65%	Typical Results	0.29-0.55%
Glycine	Possible Values	0.25-0.45%	Typical Results	0.31-0.40%
Alanine	Possible Values	0.40-1.00%	Typical Results	0.50-0.90%
Isoleucine	Possible Values	0.20-0.45%	Typical Results	0.24-0.40%
Proline	Possible Values	0.60-1.05%	Typical Results	0.66-0.93%
Leucine	Possible Values	1.60-1.50%	Typical Results	0.72-1.31%
Glutamic Acid	Possible Values	1.15-2.30%	Typical Results	1.32-2.04%
Aspartic Acid	Possible Values	0.50-0.90%	Typical Results	0.59-0.80%

Of these, the first five – cystine, methionine, lysine, threonine, and tryptophan – are usually considered the most critical in balancing a feed ration. Amino acids are reported on a dry basis percentage. Desired levels are dependent on the end user.

Fatty Acid Profile – Corn

The Fatty Acid Profile is available using wet chemistry (Gas Chromatography) methods.

The Fatty Acid Profile provides an analysis of the fatty acid content of a corn sample. Fatty acids are components of lipids (fats and oils). Levels of various fatty acids in livestock rations have been shown to affect animal nutrition and meat quality.

In this test, a ground sample of corn is analyzed using a NIR spectrophotometer. The instrument uses a calibration to evaluate the level of 5 individual fatty acids:

Oleic Acid	Possible Values	5-40%	Typical Results	15-37%
Linoleic Acid	Possible Values	50-75%	Typical Results	55-78%
Linolenic Acid	Possible Values	0.85-1.40%	Typical Results	0.93-1.34%
Palmitic Acid	Possible Values	8-13%	Typical Results	9.3-12.5%
Stearic Acid	Possible Values	1.3-4.0%	Typical Results	1.4-3.0%

Fatty acids are reported on a dry basis percentage. Desired levels are dependent on the end user.

Protein Content – Combustion Method

The Combustion (Dumas) Method can be used to measure the protein or nitrogen content in a wide range of substances. It has replaced the slow, dangerous, and environmentally unfriendly Kjeldahl procedure for most applications. The combustion method is an approved method and has become the most common reference ("wet chemistry") method for NIR calibrations for protein content. The combustion method is typically employed for samples for which no NIR calibration exists. The IPG Lab does offer protein content for corn using NIR. There are situations in which the combustion method may not be suitable.

In this test, a 50-300 mg representative sample (liquid or ground solid) is burned at high temperature in a sealed system. The nitrogen in the sample is converted to nitrogen gas, separated from the other chemical components, and measured by thermal conductivity. The nitrogen content can be converted to protein content by using a conversion factor (typically 6.25 x nitrogen) to obtain the "as is" protein percentage. This test is performed in duplicate, and the moisture content in the original sample is determined by the air oven method to convert the protein content to dry basis.

Protein contents measured by the combustion method can range from very low (0.1% to 90+%).

Oil Content – Ether Extraction

Ether extraction can be used to quantify the amount of fat or oil in a sample. The ether extraction method is an approved method and is a common reference ("wet chemistry") method for NIR calibrations for oil content. The ether extraction method is typically employed for samples for which no NIR calibration exists. The IPG Lab does offer oil content for corn using NIR. There are situations in which ether extraction may not be a suitable method for oil measurement.

In this test, a representative sample is ground and extracted in refluxing petroleum ether. Extracted oil is captured in the boiling flask. The oil is separated from the ether and weighed to determine the percentage of the original sample weight collected as oil to obtain the "as is" oil percentage. This test is performed in duplicate, and the moisture content in the original sample is determined by the air oven method to convert the protein content to dry basis.

Oil contents measured by the ether extraction method can range from very low (0.2% to 50+%).

Moisture Content – Air Oven

The Air Oven method can be used to quantify the amount of water in a sample. The air oven method is an approved method and is a common reference (“wet chemistry”) method for NIR calibrations for moisture content. The air oven method is typically employed for samples for which no NIR calibration or other reliable rapid method (NIR or Moisture Meter) exists. There are situations in which the air oven method may not be a suitable method for moisture measurement.

In this test, a representative sample (liquid or ground solid) is weighed into a tared cup and placed in an oven. Oven temperatures and residence times vary by substance. The dried sample is cooled is a dessicator and the weight of the remaining material is recorded. The weights may be used to determine the amount of water removed in the oven. Moisture content is reported as the amount of water removed from the original sample. Solids content is the weight of material remaining after drying divided by the original sample weight. Moisture content and solids content are reported as an “as is”, or wet basis percentage.

They are related by the equation: ***Moisture Content (as is) + Solids Content (as is) = 100%***

Amylose Content

The Amylose Content test measures the amount of amylose starch in a starch sample. Starch can be thought of as a chain where each link is a sugar (glucose) molecule. Corn starch is comprised of two types of starch – amylose and amylopectin. Amylopectin starch “chains” branch every 12-60 “links”. Amylose starch chains have no branching and reach 100-1000 links in length. Because of these differences, starches with various levels of amylose and amylopectin have different functional characteristics in food and industrial uses.

Most corn grown in the U.S. has approximately 27% amylose and 73% amylopectin. Waxy corn is 100% amylopectin. Hybrids have been developed with amylose contents reaching 50-80%.

In this test, starch is first isolated from the grain using a series of steeping, grinding, screening, and centrifuging steps. The starch is then chemically treated to form a colored solution. Higher amylose levels correspond to deeper blue coloration. The degree of color is read on a spectrophotometer and compared to known standards to obtain the result. The amylose content is reported as the dry basis percentage of the total starch that is amylose.

Possible Values 0-85% Typical Results 23-80%

Waxy Purity

The Waxy Purity Test measures the contamination of non-waxy corn in a waxy corn sample.

Starch can be thought of as a chain where each link is a glucose sugar molecule. Corn starch is comprised of two types of starch – amylose and amylopectin. Amylopectin starch “chains” branch every 12-60 “links”. Amylose starch chains have no branching and reach 100-1000 links in length. Because of these structural differences, starches with various levels of amylose and amylopectin have different functional characteristics in food and industrial uses.

Most corn grown in the U.S. has approximately 27% amylose and 73% amylopectin. Waxy corn is 100% amylopectin.

In this test, two replicates of 100 kernels each are evaluated. The crown, or starch cap, of each kernel is removed, and the exposed endosperm is sprayed with an iodine solution. Waxy kernels stain reddish-brown. Any kernels containing amylose stain blue. A visual rating is made and reported as percent waxy kernels.

Possible Values 0-100% Typical Results 95-100%

Aflatoxin

Aflatoxin has been described as the most potent naturally occurring carcinogen. It is a mycotoxin (fungal toxin) produced by the fungus *Aspergillus flavus*. The fungus does not produce the toxin unless environmental conditions are favorable. Sustained high temperatures (nighttime lows above 70°F) and drought stress are typically required. As such, aflatoxin is usually more of a concern in south Texas than in the Corn Belt, but aflatoxin can potentially turn up anywhere.

For this test, a GIPSA-approved quantitative strip test is utilized to quantify the aflatoxin level of a sample. The U.S. Food and Drug Administration set maximum levels for aflatoxin contamination according to these guidelines: 20 parts per billion for food for human consumption and feed for some animal species; 300 ppb for feedlot cattle; 200 ppb for market hogs; and, 100 ppb for breeding cattle, breeding hogs and mature poultry. The test result is reported in parts per billion.

Possible Values 0-300+ ppb Typical Results 0-30 ppb

Fumonisin

Fumonisin is a corn mycotoxin (fungal toxin) produced by the fungus *Fusarium moniliformae*. Fumonisin is known to cause equine leukoencephalomalcia in horses and pulmonary edema in pigs that eat contaminated corn.

For this test, a GIPSA-approved quantitative strip test is utilized to quantify the aflatoxin level of a sample. The test result is reported in parts per million (ppm). The U.S. Food and Drug Administration has set guidance levels for fumonisin content in corn and corn products that vary depending on use.

Possible Values 0-50+ ppm Typical Results 0-6 ppm

Vomitoxin (Deoxynivalenol - DON)

Vomitoxin is a grain mycotoxin (fungal toxin) produced by the fungus *Fusarium graminearium*. Vomitoxin appears to affect swine to a larger degree than other animals. The most common effect of feeding corn containing DON to swine is weight loss or reduced weight gain due to refusal of feed, reduced feed intake, or vomiting after eating. This has been observed at levels as low as 5 ppm.

For this test, a GIPSA-approved quantitative strip test is utilized to quantify the vomitoxin level of a sample. The U.S. Food and Drug Administration set maximum levels for vomitoxin contamination according to these guidelines: 1 part per million for wheat products for human consumption, 10 ppm for ruminating beef and feedlot cattle (not to exceed 50% of the diet), and 5 ppm in grain and grain products destined for swine and all other animals (not to exceed 20% of the diet).

Possible Values 0-20+ ppm Typical Results 0-2 ppm

Processing Characteristics

100 Gram Wet Mill Process Test

Wet milling is the process of separating or refining corn into its components: starch, gluten (protein), fiber, germ, and soluble material. An individual industrial plant may do this at a rate of 100,000 to 500,000 bushels per day. The starch may be converted to sugars, ethanol, or other products. The germ is processed for its oil. The remaining components are primarily used as animal feed.

The 100 gram wet mill process test mimics the industrial process to evaluate small samples for suitability in this process. This can be used to select hybrids or evaluate other physical or chemical treatments.

This test is performed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign.

Results are reported as the dry basis percentage yield of the initial corn sample.

Starch Yield	Possible Range 55-70%	Typical Results 62-69%
Gluten Yield	Possible Range 8-13%	Typical Results 9.5-12%
Germ Yield	Possible Range 4-7.5%	Typical Results 4.5-7%
Coarse Fiber Yield	Possible Range 3.5-7%	Typical Results 4-6%
Fine Fiber Yield	Possible Range 5.5-11%	Typical Results 6-9%
Total Fiber Yield	Possible Range 11-16	Typical Results 11.5-14
Steepwater Solids (solubles)	Possible Range 3.5-4.7	Typical Results 3.6-4.4
Total Recovery	Possible Range 97.80-100+%	Typical Results 98.4-100%

The starch from the 100 gram wet mill test can be analyzed for protein content, a key quality factor to wet millers. Other product analysis (oil content of the germ, protein content in the gluten, etc.) is also available.

The test is labor-intensive; the number of samples milled per day is quite limited (40 per week). The NIR Extractable Starch test may alternatively or additionally be used to rapidly obtain the predicted starch yield of the sample.

1 Kg Wet Mill Process Test

The 1 Kg Wet Mill Process Test produces the same type of data as the 100 gram wet mill test. The 1 kg method is often used by researchers desiring to have substantial product after milling to perform additional testing. There is no distinction made between coarse fiber and fine fiber in the 1 kg process.

This test is performed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign.

Results are reported as the dry basis percentage yield of the initial corn sample.

Pilot Scale Wet Milling

Pilot Scale Wet Milling is used primarily by entities that require very large (20-60 lbs) quantities of starch or other components for additional testing.

This test is performed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign.

Results are reported as the dry basis percentage yield of the initial corn sample.

1 Kg Dry Mill Process

Dry Milling is the process of processing corn by physically separating the pericarp, germ, and endosperm components. The endosperm is captured as grits of various size, meals, and flour. The germ is processed to recover the oil. The remaining components are primarily used as animal feed.

The 1 Kg Dry Mill Process Test mimics the industrial process to evaluate small samples for suitability in this process. This can be used to select hybrids or evaluate other physical or chemical treatments.

This test is performed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign.

Results are reported as the dry basis percentage yield of the initial corn sample.

Pilot Scale Dry Milling

Pilot Scale Dry Milling is used primarily by entities that require very large quantities of starch or other components for additional testing.

This test is performed at the Agricultural and Biological Engineering Department at the University of Illinois at Urbana-Champaign.

Results are reported as the dry basis percentage yield of the initial corn sample.

Endosperm Hardness

The primary characteristic desired by essentially all food-grade corn users is a large fraction of hard endosperm. Hardness is important for several reasons. It has been found that kernels with high levels of hard (also referred to as vitreous, horneous, or horny) endosperm are more resistant to breakage during handling. This has two positive consequences for a food corn processor. First, when the corn is cleaned over screens as it enters the processing facility or elevator, a smaller amount of the corn (for which a premium has most likely been paid) will pass through the screens to become low-value animal feed. More importantly is the effect of breakage on the process.

For a dry miller, profits depend highly on the amount of large “flaking” grits that are produced. Flaking grits are the highest value endosperm product, followed by smaller grits, meals, and then flour. If the kernels are broken significantly, there is less opportunity to produce the large grits. It is always possible to mill large pieces further to make smaller pieces as required; the reverse is impossible.

In the case of an alkaline cooker, (tortilla, tortilla chip maker, etc.) broken kernels lead to inconsistent cooking. The result of this is overcooked kernels which can lead to a sticky dough (masa) that may slow the process or even cause expensive downtime. If the cooking time is reduced to prevent this, the opposite may occur – undercooked particles which give the dough and resulting product a gritty texture. Product composition and color, as well as process stability, can also be affected by hardness and breakage.

Near Infrared (NIR) Spectroscopy

Near-Infrared (NIR) Spectroscopy utilizes the reflective or transmissive properties of specific wavelengths of light (the near-infrared band) in a sample. The term for these properties across a range of wavelengths is “spectra”. The instrument for measuring these characteristics is called a spectrophotometer.

It is possible to predict chemical or physical characteristics of a sample based on comparison of its spectra to the spectra of samples of known characteristics as determined by traditional laboratory reference methods. The NIR method is approved for analysis of many agricultural products and is much faster and less expensive than wet chemistry when many samples are to be evaluated.

However, the startup costs for NIR are relatively high due to the technical nature of the equipment and the need for a calibration. The calibration, or model, merges the spectral and laboratory data of calibration samples in order to predict information about unknown samples. If the sample spectra are not similar enough to the calibration spectra, the calibration will not be able to accurately analyze the sample. The greater the diversity and scope of the calibration samples, the more accurate and capable the calibration will be. Some companies develop calibrations for licensing to other parties, eliminating the need for duplication of extensive laboratory testing effort among NIR users.

Moisture Basis (wet or dry)

Chemical and physical components are sometimes reported on an "as is" (wet) basis or dry (0% moisture) basis.

A wet basis result is the percentage of the component of interest out of the entire sample including moisture. A dry basis result is the percentage of the component out of the entire sample neglecting moisture.

For example:

> A soybean sample is analyzed to contain 38% protein, 10% moisture, and 52% other components as it sits in a sample container. The protein content is 38% on a wet basis. Since 10% of the sample is water, 90% is "dry material". Thus 38 parts protein divided by 90 parts of dry material gives a protein content of 42.2% dry basis.

The IPG Lab reports moisture contents on an "as is" basis. All other results are generally reported on dry basis (if applicable) so comparisons are not skewed by differing moisture bases.

Conversion for a value at one moisture content (represented by V_1, & M_1) to the corresponding value at a different moisture content (V_2 & M_2) can be performed according to the equation:

$$V_2 = [(100-M_2) / (100-M_1)] \times V_1$$

To use the previous example:

$$\text{Protein}_{\text{(0\% moisture)}} = [(100-0) / (100-10)] \times 38\%$$

$$\text{Protein}_{\text{(0\% moisture)}} = [(100) / (90)] \times 38\% = 1.11 \times 38\% = 42.2\%$$

This equation will work for conversion between any two moisture contents.

Alkaline Cooking Process

The Alkaline Cooking Process is used to make corn chips, corn tortillas, and corn tortilla chips. While many tortillas in the United States are made from wheat flour, corn tortillas the traditional favorite throughout Latin America**.**

In the alkaline cooking process, corn is cooked in a 0.5-2% lime (calcium hydroxide) solution at 98-100°C for 5-60 or more minutes. The traditional name for the cooked corn is nixtamal; the cooking process is nixtamalization. During nixtamalization, the pericarp (outer seed covering) is dissolved. The dissolved pericarp is rinsed away and the nixtamal is ground to make “masa” (tortilla dough). The masa can be flattened by several methods and baked to a finished tortilla.

To make corn tortilla chips, masa is formed into a thin sheet and cut to the desired chip shape. The raw chips are toasted to remove some of the water (imparting the characteristic black “toast points” observable on one side of a chip) then fried in hot oil. Additional seasonings or flavorings may be added. Corn chips do not undergo the toasting process. The raw dough is form into chips and fried immediately.

Corn Dry Milling Process

Corn Dry Millers physically separate corn into grits, flour, and meal.

Incoming corn is “tempered” for 10-45 minutes by adding water (liquid or steam) to raise the moisture content of the grain. The moisture will primarily enter through the “tip cap” (cob attachment point) of the kernel and be absorbed by the germ and the cells between the pericarp (outer seed covering) and the endosperm. This moisture differential between various kernel components promotes efficient separation.

The tempered corn enters a degerminating mill. The goal at this stage is to rub or peel the pericarp from the kernel and then to remove the germ from the endosperm. It is strongly desired to have the endosperm remain as intact as possible while getting clean separation of the germ and pericarp. A series of screening, grinding, rolling, and aspiration steps are performed to separate the corn into the desired finished products.

High flaking grit yield has traditionally been the goal of the dry miller. Flaking grits are large pieces of endosperm (approximately two grits per kernel) that are used to make corn flakes. One grit makes one flake; bigger grits make bigger flakes. Big grits can be made smaller. You cannot make big grits from smaller ones. The grits are cooked, rolled, and toasted to make the flakes. Other endosperm material is separated into smaller grits, meals, and flour based on particle size requirements. The germ is processed to remove the oil. The spent germ, pericarp, and tip cap fractions are sold as a low-value animal feed.

Corn Wet Milling Process

The Corn Wet Milling Process separates corn by physical and chemical methods to produce starch, high protein animal feed, and corn oil. The starch is often processed further to make corn syrup, corn sugar, ethanol, or other products.

Cleaned (fine materials removed) corn is steeped in a weak sulfurous acid solution for 24 to 48 hours at temperature close to 50°C (122°F). The kernels absorb moisture, and the sulfurous acid breaks chemical bonds in the protein matrix which encapsulates the starch granules. After steeping, the corn is loosely ground to rupture the pericarp (outer seed covering) and release the germ (ideally intact). The germ is removed by utilizing its difference in density from the rest of the components (i.e. it floats). The remainder of the material is ground more finely and separated by screening methods (to remove fiber) and differences in density (starch from protein).

The primary goal of the wet miller is high starch yield. Genetics and environment can affect starch yields. A corn sample may contain 73 grams of starch for every 100 grams of dry corn material. Typically around only 66 (around 90%) of those 73 grams of starch are recovered after processing as “starch”. The other seven grams end up in the low-value feed products. In the U.S. the feed and oil are valuable co-products that produce significant revenue for the miller. In other markets, such as Japan, there is little value placed on the co-products. High starch yield is a requirement there.

Dry-Grind Ethanol Process

The dry-grind ethanol producer converts corn into fuel ethanol. This is the fastest growing area of corn processing

Dry corn is ground, mixed with water, and cooked with enzymes to break the starch in the corn down to sugars. The sugars are then fermented into ethanol. The residual solids (Distillers Dried Grains with Solubles – DDGS) are used for animal feed. Much research is being done to improve the economics of the dry-grind process by various means, particularly by capturing more value from the materials traditionally sold as DDGS.