# 2016/2017

U.S. GRAINS COUNCIL

# CORN HARVEST QUALITY REPORT

U.S. GRAINS COUNCIL

# ACKNOWLEDGEMENTS

Developing a report of this scope and breadth in a timely manner requires participation by a number of individuals and organizations. The U.S. Grains Council (Council) is grateful to Dr. Sharon Bard and Mr. Chris Schroeder of Centrec Consulting Group, LLC (Centrec) for their oversight and coordination in developing this report. They were supported by internal staff along with a team of experts that helped in data gathering, analysis, and report writing. External team members include Drs. Tom Whitaker, Lowell Hill, Marvin R. Paulsen, and Fred Below. In addition, the Council is indebted to the Illinois Crop Improvement Association's Identity Preserved Grain Laboratory (IPG Lab) and Champaign-Danville Grain Inspection (CDGI) for providing the corn quality testing services.

Finally, this report would not be possible without the thoughtful and timely participation by local grain elevators across the United States. We are grateful for their time and effort in collecting and providing samples during their very busy harvest time.

U.S. GRAINS COUNCIL

The U.S. Grains Council (USGC) has conducted its sixth annual corn quality survey and is pleased to present the findings in this *2016/2017 Corn Harvest Quality Report*.

The Council is committed to providing accurate and timely information about the quality of the U.S. corn crop as it comes out of the field. Such information helps buyers make well-informed decisions and increases their confidence in the capacity and reliability of the U.S. corn market.

This year's corn crop had an excellent crop condition during reproductive growth, as well as high yields, particularly from the western Corn Belt. Overall, 2016 was characterized by a warm, dry vegetative period, followed by a warm and wet grain-filling period and harvest. Such favorable weather conditions in the United States have led to a projected record amount of corn in 2016 available for export.

As in past editions, the *2016/2017 Corn Harvest Quality Report* provides information about the quality of the current U.S. crop at harvest as it enters international merchandising channels, using consistent methodology to allow for comparison with past years' quality. Corn quality observed by buyers will be further affected by subsequent handling, blending and storage conditions. A second Council report, the *2016/2017 Corn Export Cargo Quality Report*, will measure corn quality at export terminals at the point of loading for international shipment and will be available in early 2017.

The Council strives for global food security and mutual economic benefit through the expansion of trade and overseas market development. Our global staff serves as a bridge between international corn buyers and the world's largest and most sophisticated agricultural production and export system.

As part of this role, the Council is pleased to offer this report as a service to our partners in support of the Council's mission of developing markets, enabling trade, and improving lives. We hope you find this report valuable.

Sincerely,

Phillip "Chip" Councell, Jr.
Chairman, U.S. Grains Council
December 2016

EXPANDING TRADE EXPANDING OPPORTUNITIES

The overall quality of the 2016 corn crop was better than the average of the previous five crop years (5YA[1]) on most attributes, with 87.8% of the samples meeting the standards for U.S. No. 2 grade or better. In addition to desirable average levels of grade factors, the 2016 U.S. corn crop is entering the market channel with higher average test weight, kernel volume, oil concentration, and whole kernels, and lower broken corn and foreign material and stress cracks relative to the 5YA.

The good quality was largely the result of a favorable corn growing season with earlier than normal planting; a warm, dry vegetative period; and a warm and wet grain filling period and harvest. U.S. corn producers experienced record high yields in 2016, resulting in the largest U.S. corn crop on record. Total U.S. corn production for 2016 is projected to be 386.8 million metric tons (15.23 billion bushels), an 11.95% increase in production over the 2015 corn crop. The United States is the top exporter of corn, with an estimated 39.2% of global corn exports during the 2016/2017 marketing year.

## Grade Factors and Moisture

- Average test weight of 58.3 lb/bu (75.0 kg/hl), with 94.9% above the limit for No. 1 grade corn, and 99.5% above the limit for No. 2 grade. Higher than 2015 and 5YA, this test weight indicates good kernel filling and maturation.
- Low levels of broken corn and foreign material (BCFM) (0.7%), with 96.6% below the limit for No. 1 grade, indicating little cleaning will be required.
- Average total damage of 2.6%, higher than 2015, 2014, and 5YA. While 89.3% of the samples were below the limit for No. 2 grade, some care should be given to monitoring and properly aerating corn for safe storage.
- No observed heat damage.
- Higher elevator moisture content (16.1%) than 2015, yet same as 5YA. The distribution shows 33.1% of the samples were below 15% moisture content, and only 28.4% of the samples were above 17% moisture content. This distribution indicates more samples required drying than in 2015, but still less than in 2014.

## Chemical Composition

- Higher protein concentration (8.6% dry basis) than 2015 and 2014, but slightly lower than 5YA.
- Lower starch concentration (72.5% dry basis) than 2015, 2014, and 5YA.
- Average oil concentration of 4.0% (dry basis), higher than 2015, 2014, and 5YA.

[1] *5YA represents the simple average of the quality factor's average or standard deviation from the 2011/2012, 2012/2013, 2013/2014, 2014/2015, and 2015/2016 Harvest Reports.*

## *Physical Factors*

- Low percentage of stress cracks (4%) and stress crack index (8.8), slightly higher than 2015, but below 2014 and 5YA, with 91.7% of samples having stress cracks less than 10%. The low percentage of stress cracks is likely due to excellent field dry-down conditions at harvest with less artificial drying needed than in wetter years. Susceptibility to breakage should remain relatively low.
- Higher 100-k weight (35.20 g) than 2015, 2014, and 5YA, signifying larger kernels than in previous years.
- Average kernel volumes of 0.28 $cm^3$, slightly higher than 2015, 2014, and 5YA.
- Average true density of 1.258 $g/cm^3$, higher than 2015, similar to 2014, and lower than 5YA.
- Similar average horneous endosperm (79%) to 2015, but lower than 2014 and 5YA, indicating softer kernels compared to 2014 and 5YA.
- Higher average whole kernels (95.2%) than 2015, 2014, and 5YA. The high percentage of whole kernels and relatively low stress cracks indicate the corn should have fewer broken kernels during handling than in previous years.

## *Mycotoxins*

- All but one sample, or 99.4%, of the 2016 corn samples tested below the FDA action level of 20 ppb.
- In 2016, 100% of the corn samples tested below the 5 ppm FDA advisory level for DON (same as in 2015 and 2014). However, there were more samples showing levels of DON above the FGIS “Lower Conformance Level” in 2016 than in 2015 and 2014. This increase may be attributed to the wet weather conditions, which were more conducive to DON development in 2016 than in the previous two years.

# INTRODUCTION

The *U.S. Grains Council 2016/2017 Corn Harvest Quality Report* has been designed to help international buyers of U.S. corn understand the initial quality of U.S. yellow commodity corn as it enters the merchandising channel. This is the sixth annual measurement survey of the quality of the U.S. corn crop at harvest. Six years of results are showing patterns in the impact of weather and growing conditions on the quality of U.S. corn as it comes out of the field.

Spring 2016 was warmer than average for almost all of the United States, with wide variation in temperatures and precipitation. These factors led to prolonged emergence that, on average, was earlier than the 5 year average (5YA) emergence. Warm, dry weather during the vegetative stage encouraged rapid growth and healthy-looking plants. In June, the warm weather and dry conditions favored brisk plant growth and nitrogen fertilizer uptake, producing a crop with a combined Good or Excellent condition rating between 70-75% that remained all season. These Good or Excellent growth conditions were similar to the 2014 crop. The summer's above-average temperatures in the Gulf and Southern Rail Export Catchment Areas (ECAs) were mostly associated with warmer nights, potentially causing starch-accumulation stress during grain-fill and leading to the lower starch concentrations found in 2016. The wet reproductive period with warm nights created conditions conducive to possible fungal diseases. The total damage average was higher than in past years, but was still well within the limits for U.S. No. 1 grade.

Although this year's crop matured faster than previous years, abundant rains hindered a timely harvest in several regions, resulting in a few areas of high-moisture corn. However, despite the delayed harvest in these regions, drier areas advanced more quickly to harvest.

Overall, the 2016 season experienced an about-average harvest duration, and early-harvested grain will be dried to prevent possible disease spread. Average moisture content was relatively low, and whole kernel percentages were higher than preceding years, which, with the observed low stress cracks, should lead to low breakage susceptibility in handling and good storability. Overall, the weather in 2016 led to high yields, with high test weight, large kernels, low stress cracks, and high oil concentration averages.

These observations show quality differences among the six years, but overall, the *2016/2017 Harvest Report* indicates good quality corn entering the 2016/2017 market channel. 65.5% of the samples meet all requirements for No. 1 grade, and 87.8% meet No. 2 grade or better. Average moisture content and total damage values show a crop that will store and handle well as it moves through the market channel to export.

Six years of data have laid the foundation for evaluating trends and the factors that impact corn quality. In addition, the cumulative *Harvest Report* measurement surveys enable export buyers to make year-to-year comparisons and assess patterns of corn quality based on crop growing conditions across the years.

This *2016/2017 Harvest Report* is based on 624 yellow commodity corn samples taken from defined areas within 12 of the top corn-producing and exporting states. Inbound samples were collected from local grain elevators to observe quality at the point of origin and to provide representative information about the variability of the quality characteristics across the diverse geographic regions.

The sampling areas in the 12 states are divided into three general groupings that are labeled Export Catchment Areas (ECAs). These three ECAs are identified by the three major pathways to export markets:

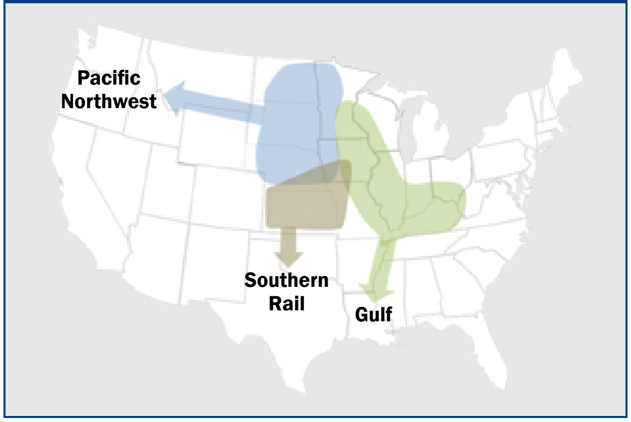
- The Gulf ECA consists of areas that typically export corn through U.S. Gulf ports;
- The Pacific Northwest (PNW) ECA includes areas exporting corn through Pacific Northwest and California ports; and
- The Southern Rail ECA comprises areas generally exporting corn to Mexico by rail from inland subterminals.

Sample test results are reported at the U.S. Aggregate level and for each of the three ECAs, providing a general perspective on the geographic variability of U.S. corn quality.

The quality characteristics of the corn identified at harvest establish the foundation for the quality of the grain ultimately arriving at the export customers' doors. However, as corn passes through the U.S. marketing system, it is mingled with corn from other locations; aggregated into trucks, barges, and rail cars; and stored, loaded, and unloaded several times. Therefore, the quality and condition of the corn changes between the initial market entry and the export elevator. For this reason, the *2016/2017 Harvest Report* should be considered carefully in tandem with the *U.S. Grains Council 2016/2017 Corn Export Cargo Quality Report* that will follow early in 2017. As always, the quality of an export cargo of corn is established by the contract between buyer and seller, and buyers are free to negotiate any quality factor that is important to them.

This report provides detailed information on each of the quality factors tested, including averages and standard deviations for the aggregate of all samples, and for each of the three ECAs. The "Quality Test Results" section summarizes the following quality factors:

**EXPORT CATCHMENT AREAS**




- Grade Factors: test weight, broken corn and foreign material (BCFM), total damage, and heat damage
- Moisture
- Chemical Composition: protein, starch, and oil concentrations
- Physical Factors: stress cracks/stress crack index, 100-kernel weight, kernel volume, kernel true density, whole kernels, and horneous (hard) endosperm
- Mycotoxins: aflatoxin and DON

In addition, this *Harvest Report* includes brief descriptions of the U.S. crop and weather conditions; U.S. corn production, usage, and outlook; and detailed descriptions of survey, statistical analysis, and testing analysis methods.

New to this *2016/2017 Harvest Report* is a simple average of the quality factors' averages and standard deviations of the previous five *Harvest Reports* (*2011/2012, 2012/2013, 2013/2014, 2014/2015,* and *2015/2016*). These simple averages are calculated for the U.S. Aggregate and each of the three ECAs, and are referred to as "5YA" in the report.

# A. GRADE FACTORS

The U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) has established numerical grades, definitions, and standards for measurement of many quality attributes. The attributes which determine the numerical grades for corn are test weight, broken corn and foreign material (BCFM), total damage, and heat damage. The table for "U.S. Corn Grades and Grade Requirements" is provided on page 70 of this report.

## SUMMARY: GRADE FACTORS AND MOISTURE

- Average U.S. Aggregate test weight (58.3 lb/bu or 75.0 kg/hl) was higher than 2015, 2014, and 5YA. It was well above the limit for U.S. No. 1 grade corn.
- As in previous years, the average test weight was above the minimum for U.S. No. 1 grade in all ECAs.
- Average U.S. Aggregate broken corn and foreign material (BCFM) (0.7%) was less than in 2015, 2014, and 5YA, and well below the maximum for U.S. No. 1 grade. Low BCFM indicates minimal cleaning required for corn delivered to the first handler and should facilitate good aeration during storage.
- BCFM levels in almost all (99.2%) of the corn samples were equal to or below the 3% maximum allowed for No. 2 grade.
- Average BCFM was the same (0.7%) in all three ECAs.
- Average U.S. Aggregate broken corn (0.5%) was slightly lower than previous years and 5YA.
- Average U.S. Aggregate foreign material (0.1%) was slightly lower than in previous years and 5YA.
- Total damage in the U.S. Aggregate samples averaged 2.6% in 2016, higher than 2015, 2014, and 5YA, but still below the limit for U.S. No. 1 grade (3%). Nearly 72% of the samples contained 3% or less damaged kernels. The standard deviation (1.61%) and range (0 to 23.1%) in total damage were higher than in previous years. With a larger percentage of samples having higher total damage than in previous years, a higher storage risk could occur if corn is not adequately dried, monitored, and properly aerated.
- The Pacific Northwest ECA had the lowest total damage in 2016, 2015, 2014, and 5YA, while the Gulf ECA had the highest total damage for 2016, 2015, 2014, and 5YA.
- No heat damage was reported on any of the samples, the same as 2015, 2014, and 5YA.
- Average U.S. Aggregate moisture content in 2016 (16.1%) was higher than 2015, lower than 2014, and the same as 5YA.
- The 2016 average moisture content value for the Southern Rail ECA (15.7%) was lower than the Pacific Northwest (15.9%) and Gulf (16.2%) ECAs' moisture content values.
- The moisture content values' distributions for 2016 and 2015 imply that more drying may have been required in 2016 than in 2015. In the 2016 crop, only 12.5% of the samples contained 14% or less moisture compared to 19.8% of the samples in 2015.

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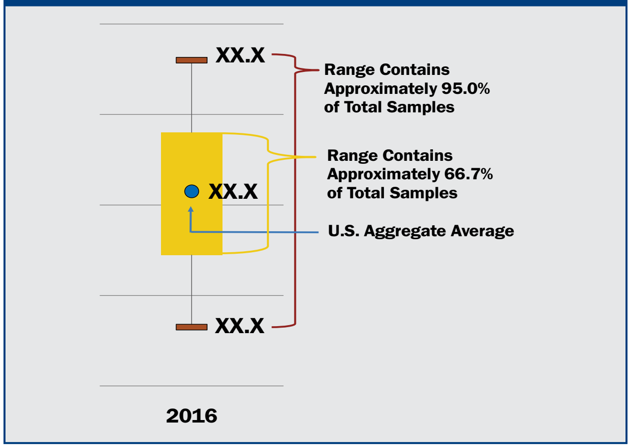
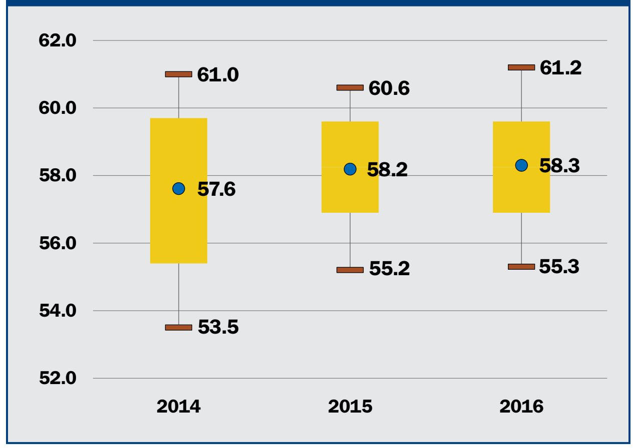
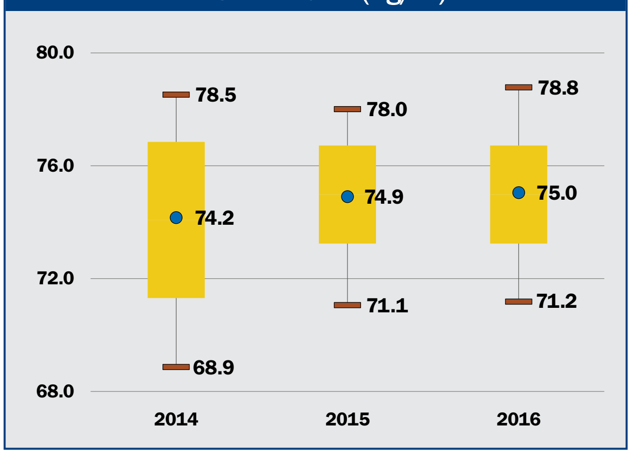
## HOW TO READ THE CHARTS



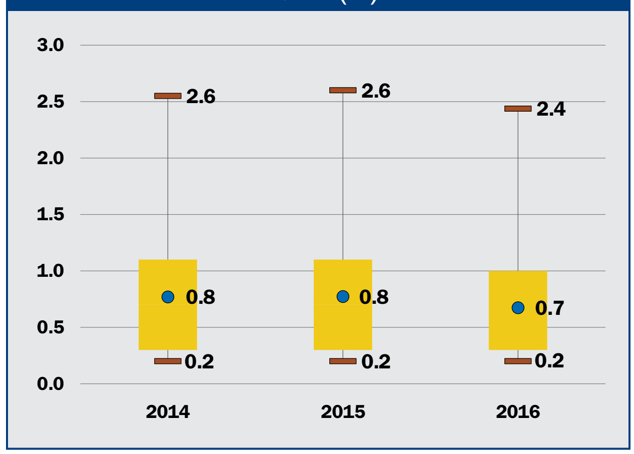

## TEST WEIGHT (lb/bu)



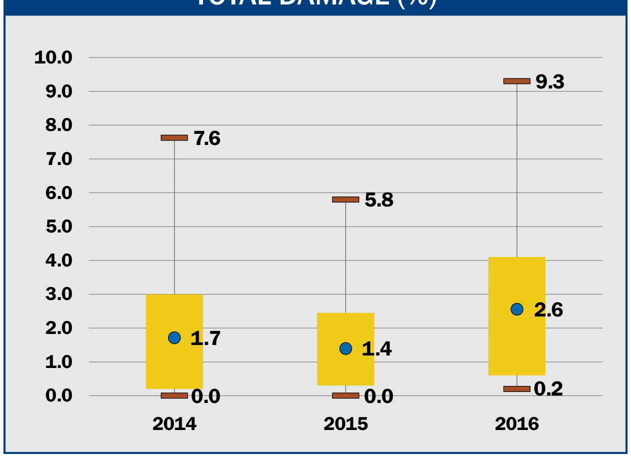

## TEST WEIGHT (kg/hl)



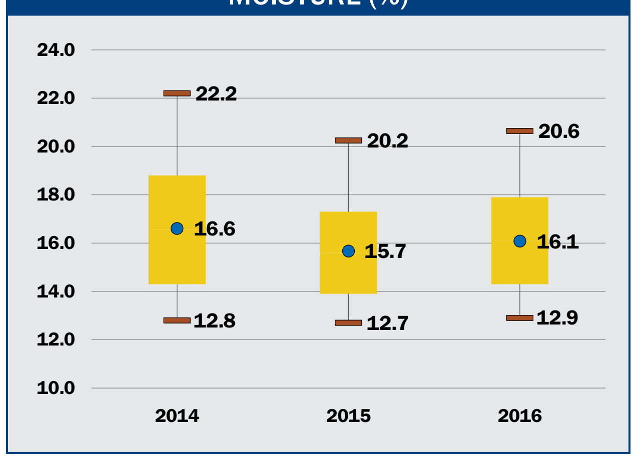

## BCFM (%)




## TOTAL DAMAGE (%)




## MOISTURE (%)



## Test Weight

Test weight (weight per volume) is a measure of bulk density and is often used as a general indicator of overall quality and as a gauge of endosperm hardness for alkaline cookers and dry millers. High test weight corn takes up less storage space than the same weight of corn with a lower test weight. Test weight is initially impacted by genetic differences in the structure of the kernel. However, it is also affected by moisture content, method of drying, physical damage to the kernel (broken kernels and scuffed surfaces), foreign material in the sample, kernel size, stress during the growing season, and microbiological damage. When sampled and measured at the point of delivery from the farm at a given moisture content, high test weight generally indicates high quality, high percent of horneous (or hard) endosperm, and sound, clean corn. Test weight is positively correlated with true density and reflects kernel hardness and kernel maturity.

### *Results*

- Average U.S. Aggregate test weight in 2016 (58.3 lb/bu or 75.0 kg/hl) was higher than 2015 (58.2 lb/bu or 74.9 kg/hl), 2014 (57.6 lb/bu or 74.2 kg/hl), and 5YA (58.1 lb/bu or 74.8 kg/hl).
- Average U.S. Aggregate test weight in 2016 was well above the minimum for U.S. No. 1 grade (56 lb/bu).
- U.S. Aggregate test weight standard deviation in 2016 (1.22 lb/bu) was higher than 2015 (1.08 lb/bu), but lower than 2014 (1.34 lb/bu) and 5YA (1.33 lb/bu), indicating more variability than 2015, but less than 2014 and 5YA.

| U.S. Grade Minimum Test Weight |
|---|
| No. 1: 56.0 lbs |
| No. 2: 54.0 lbs |
| No. 3: 52.0 lbs |

- The range in values was greater among the 2016 harvest samples (10.4 lb/bu) than 2015 (8.1 lb/bu), but similar to 2014 (10.6 lb/bu).
- The 2016 test weight values were distributed with 94.9% of the samples at or above the factor limit for U.S. No. 1 grade (56 lb/bu), compared to 94% in 2015 and 77% in 2014. In the 2016 crop, 99.5% of the samples were above the limit for U.S. No. 2 grade (54 lb/bu), compared to 99% in 2015 and 94% in 2014.
- Average test weight was above the limit for U.S. No. 1 grade in all ECAs. The Gulf (58.4 lb/bu) and Southern Rail (58.5 lb/bu) ECAs had the highest average test weights. The Pacific Northwest ECA had the lowest test weight (58.0 lb/bu) in 2016, 2015, 2014, and 5YA.
- Although the Pacific Northwest ECA had the lowest test weight in 2016, it had less variability as indicated by its lower standard deviation (1.19 lb/bu), compared to the Gulf (1.24 lb/bu) and Southern Rail (1.22 lb/bu) ECAs.

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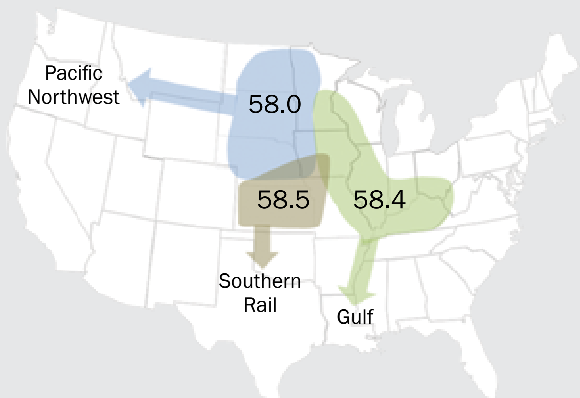
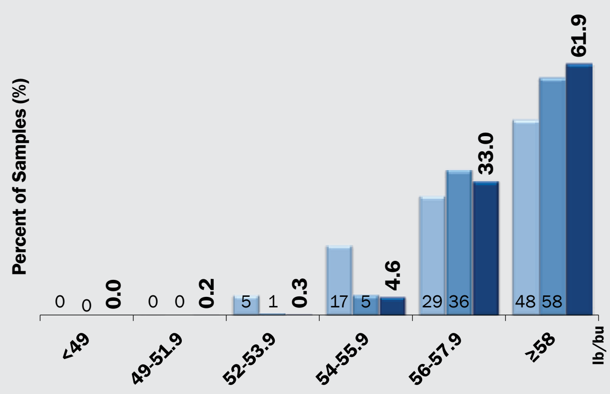
## TEST WEIGHT (lb/bu)

### EXPORT CATCHMENT AREA AVERAGE



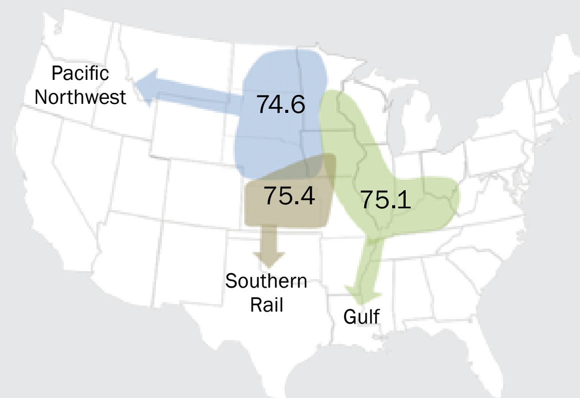

### U.S. AGGREGATE



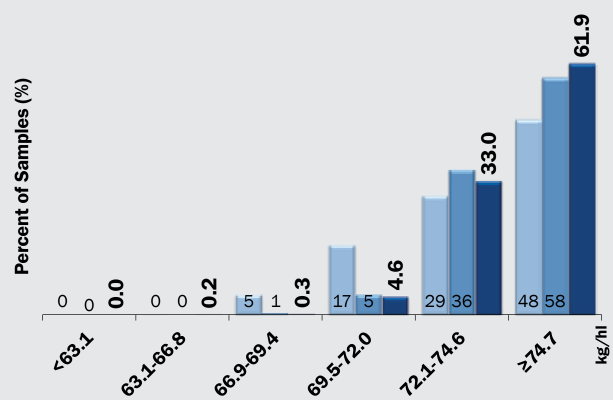

| | Avg (lb/bu) | Std Dev (lb/bu) |
|---|---|---|
| 2016 | 58.3 | 1.22 |
| 2015 | 58.2 | 1.08 |
| 2014 | 57.6 | 1.34 |

## TEST WEIGHT (kg/hl)

### EXPORT CATCHMENT AREA AVERAGE




### U.S. AGGREGATE




| | Avg (kg/hl) | Std Dev (kg/hl) |
|---|---|---|
| 2016 | 75.0 | 1.57 |
| 2015 | 74.9 | 1.38 |
| 2014 | 74.2 | 1.72 |

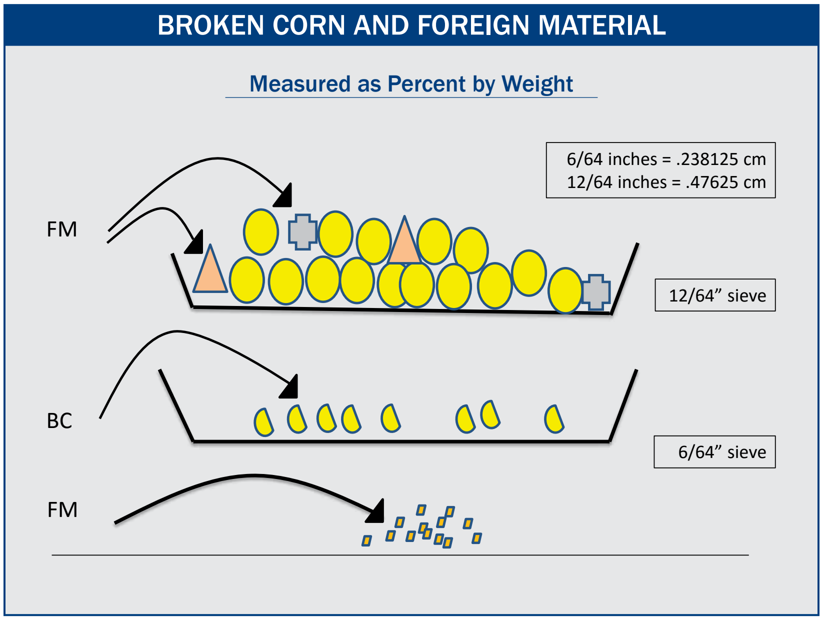
## Broken Corn and Foreign Material (BCFM)

Broken corn and foreign material (BCFM) is an indicator of the amount of clean, sound corn available for feeding and processing. The lower the percentage of BCFM, the less foreign material and/or fewer broken kernels are in a sample. Higher levels of BCFM in farm-originated samples generally stem from harvesting practices and/or weed seeds in the field. BCFM levels will normally increase during drying and handling, depending on the methods used and the soundness of the kernels. More stress cracks at harvest will also result in an increase in broken kernels and BCFM during subsequent handling.

Broken corn (BC) is defined as corn and any other material (such as weed seeds) small enough to pass through a 12/64th-inch round-hole sieve, but too large to pass through a 6/64th-inch round-hole sieve.

Foreign material (FM) is defined as any non-corn material too large to pass through a 12/64th-inch round-hole sieve, as well as all fine material small enough to pass through a 6/64th-inch round-hole sieve.

The diagram shown below illustrates the measurement of broken corn and foreign material for the U.S. corn grades.



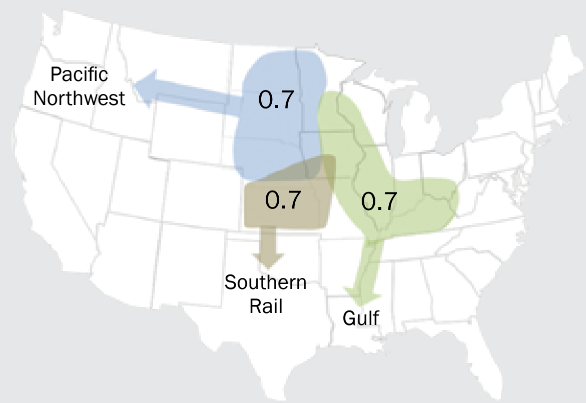
## *Results*

- Average U.S. Aggregate BCFM in 2016 (0.7%) was slightly below 2015, 2014, and 5YA (all 0.8%), and well below the maximum for U.S. No. 1 grade (2.0%).
- The variability of BCFM in the 2016 crop was slightly less than previous years' crops and 5YA, as indicated by standard deviations (0.45% in 2016, 0.61% in 2015, 0.50% in 2014, and 0.58% for 5YA).
- The range between minimum and maximum BCFM values in 2016 (4.0%) was lower than in 2015 (11.9%) and 2014 (5.8%).
- The 2016 samples were distributed with 96.6% of the samples below the maximum BCFM level for U.S. No. 1 grade (2%), compared to 95% in 2015 and 96% in 2014. BCFM levels in nearly all samples (99.2%) were equal to or below the maximum 3% limit for No. 2 grade.
- Average BCFM in all ECAs in 2016 was the same (0.7%). The average BCFM differed by no more than 0.1% in 2015, and by no more than 0.2% in 2014 and for 5YA.

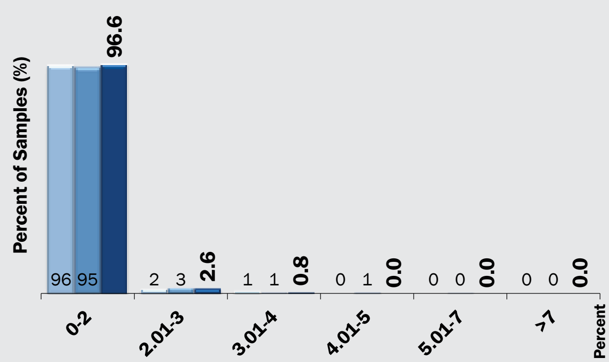
| U.S. Grade BCFM Maximum Limits |
|---|
| No. 1: 2.0% |
| No. 2: 3.0% |
| No. 3: 4.0% |

**BROKEN CORN AND FOREIGN MATERIAL (%)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 0.7 | 0.45 |
| 2015 | 0.8 | 0.61 |
| 2014 | 0.8 | 0.50 |

## Broken Corn

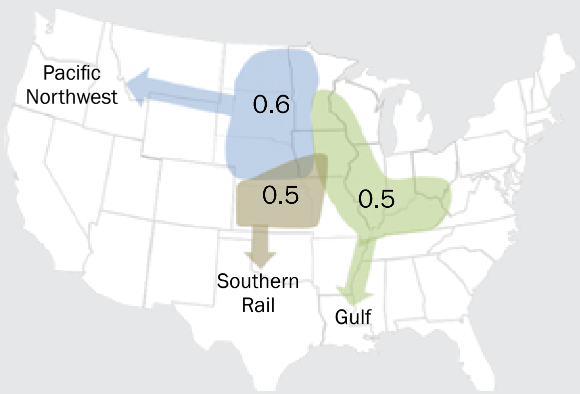
Broken corn in U.S. grades is based on particle size and usually includes a small percent of non-corn material. Broken corn is more subject to mold and insect damage than whole kernels, and it can cause problems in handling and processing. When not spread or stirred in a storage bin, broken corn tends to stay in the center of the bin, while whole kernels are likely to gravitate outward to the edges. The center area in which broken corn tends to accumulate is known as a "spout-line." If desired, the spout-line can be reduced by drawing this grain out of the center of the bin.

### *Results*

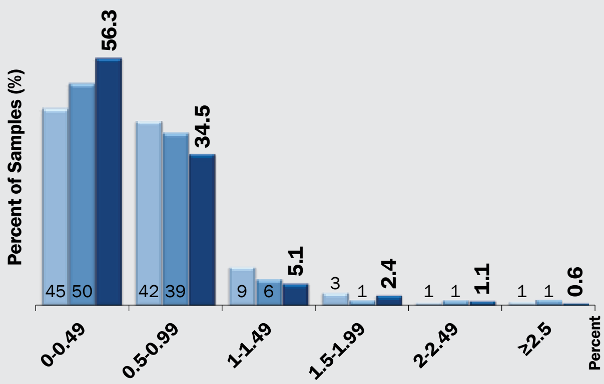
- Broken corn in the U.S. Aggregate samples averaged 0.5% in 2016, slightly lower than 2015 and 2014 (both 0.6%), and 5YA (0.7%).
- The variability of broken corn for the 2016 crop was similar to previous years and 5YA, as measured by standard deviations. Standard deviations for 2016, 2015, 2014, and 5YA were 0.34%, 0.42%, 0.36%, and 0.44%, respectively.
- The range in broken corn values in 2016 (3.8%) was narrower than 2015 (7.5%), but slightly wider than 2014 (3.2%).
- The 2016 samples were distributed with 90.8% having less than 1.0% broken corn, compared to 89% in 2015 and 87% in 2014. This lower percentage of samples with less than 1% broken corn in 2014 may have been a result of harvesting corn with higher average moisture in 2014.
- The percentage of broken corn for the Gulf, Pacific Northwest, and Southern Rail ECAs (0.5%, 0.6%, and 0.5%, respectively) differed by only 0.1% across the ECAs.
- The distribution chart on the next page, displaying broken corn as a percentage of BCFM, shows that in nearly all samples, BCFM consisted primarily of broken corn. These results were similar to what was found in previous years.

## BROKEN CORN (%)

### EXPORT CATCHMENT AREA AVERAGE



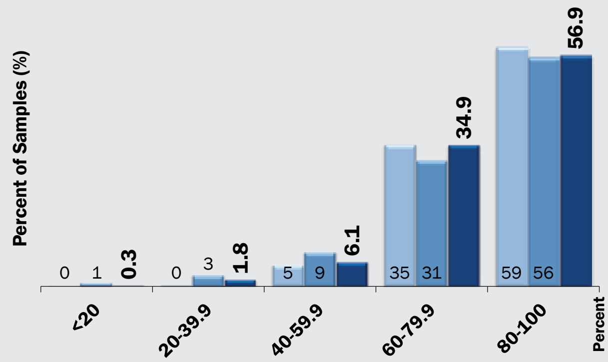

### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 0.5 | 0.34 |
| 2015 | 0.6 | 0.42 |
| 2014 | 0.6 | 0.36 |

## BROKEN CORN (%)

### BROKEN CORN AS A % OF BCFM



## Foreign Material

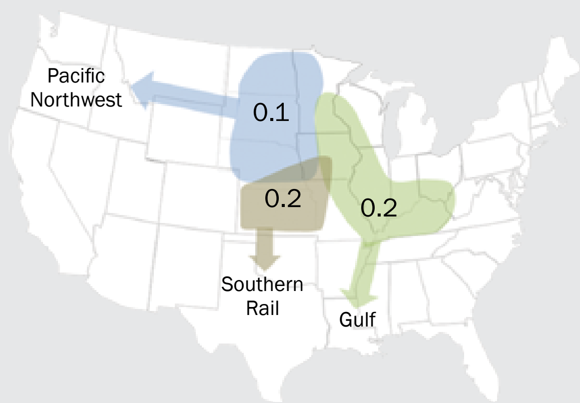
Foreign material is important because it has reduced feeding or processing value. It is also generally higher in moisture content than the corn, and therefore creates a potential for deterioration of corn quality during storage. Additionally, foreign material contributes to the spout-line (as mentioned in Broken Corn). It also has the potential to create more quality problems than broken corn, due to its higher moisture level.

### *Results*

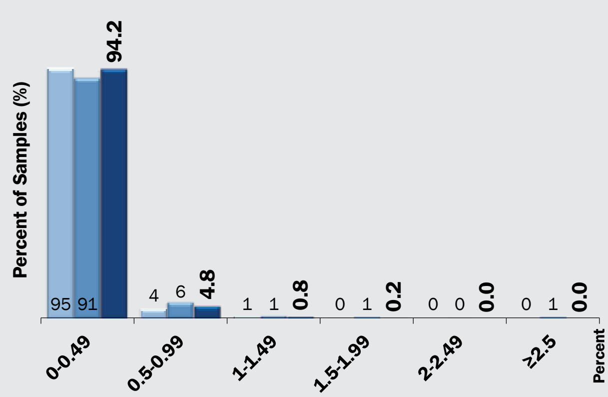
- Foreign material in the U.S. Aggregate samples averaged 0.1% in 2016, lower than 2015, 2014, and 5YA, which all had 0.2% foreign material. Combines, which are designed to remove most fine material, appear to be functioning very well, given the consistently low level of foreign material found across the years.
- Variability, measured by standard deviation, among the U.S. Aggregate samples in 2016 (0.16%) was less than 2015 (0.27%), 2014 (0.19%), and 5YA (0.22%).
- Foreign material in the 2016 samples ranged from 0.0 to 1.6%, compared to 2015 (0.0 to 4.5%) and 2014 (0.0 to 5.5%).
- In the 2016 crop, 94.2% of the samples contained less than 0.5% foreign material, compared to 91% in 2015 and 95% in 2014.
- All ECAs had average foreign material values of 0.1% or 0.2% in 2016, 2015, 2014, and 5YA.

**FOREIGN MATERIAL (%)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 0.1 | 0.16 |
| 2015 | 0.2 | 0.27 |
| 2014 | 0.2 | 0.19 |

## Total Damage

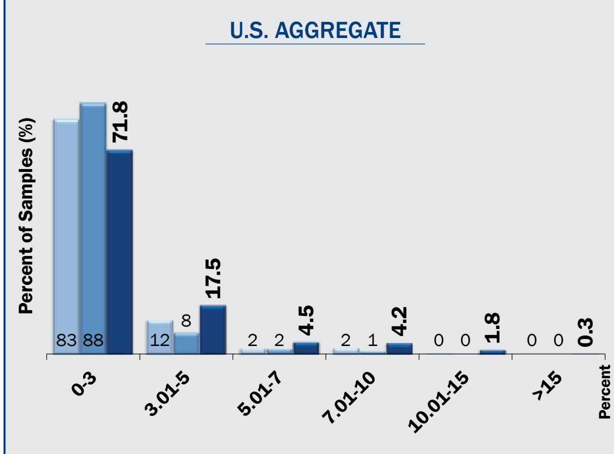
Total damage is the percentage of kernels and pieces of kernels that are visually damaged in some way, including damage from heat, frost, insects, sprouting, disease, weather, ground, germ, and mold. Most of these types of damage result in some sort of discoloration or change in kernel texture. Damage does not include broken pieces of grain that are otherwise normal in appearance.

Mold damage is usually associated with higher moisture contents and warm temperatures during the growing season and/or during storage. There are several field molds, such as Diplodia, Aspergillus, Fusarium, and Gibberella, that can lead to mold-damaged kernels during the growing season, if the weather conditions are conducive to their development. While some fungi that produce mold damage can also produce mycotoxins, not all fungi do produce mycotoxins. Chances of mold decrease as corn is dried and cooled to lower temperatures.

### *Results*

- Average U.S. Aggregate total damage (2.6%) in 2016 was higher than 2015 (1.4%), 2014 (1.7%), and 5YA (1.2%). However, the 2016 total damage average was still below the limit for U.S. No. 1 grade (3%).
- Total damage variability in the 2016 crop, as measured by the standard deviation (1.61%), was higher than 2015 (1.00%), 2014 (1.36%), and 5YA (0.97%).
- The range for total damage in 2016 (0.0 to 23.1%) was higher than in 2015 (0.0 to 13.2%) and 2014 (0.0 to 17.3%).
- Total damage in the 2016 samples was distributed with only 71.8% of the samples having 3% or less damaged kernels and 89.3% having 5% or less, compared to 2015 with 88% and 96%, respectively. Thus, the histogram shows a larger percentage of samples having total damage above 3% than in previous years. These samples could present an added storage risk if not adequately dried and properly aerated.

**TOTAL DAMAGE (%)**



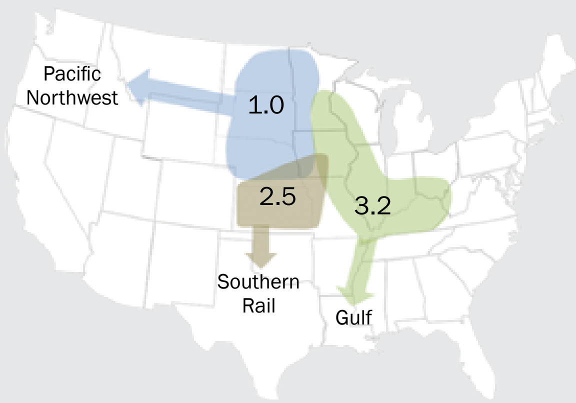

| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 2.6 | 1.61 |
| 2015 | 1.4 | 1.00 |
| 2014 | 1.7 | 1.36 |

- Average total damage by ECAs was 3.2% for Gulf, 1.0% for Pacific Northwest, and 2.5% for Southern Rail. The Pacific Northwest ECA had the lowest average total damage, and the Gulf ECA had the highest total damage for 2016, 2015, 2014, and 5YA.
- Average total damage values in all ECAs were well below the limit for U.S. No. 2 grade (5.0%).

| U.S. Grade Total Damage Maximum Limits |
|---|
| No. 1: 3.0% |
| No. 2: 5.0% |
| No. 3: 7.0% |

TOTAL DAMAGE (%)

EXPORT CATCHMENT AREA AVERAGE




## Heat Damage

Heat damage is a subset of total damage and has separate allowances in the U.S. Grade standards. Heat damage can be caused by microbiological activity in warm, moist grain or by high heat applied during drying. Heat damage is seldom present in corn delivered directly from farms at harvest.

### *Results*

- There was no heat damage reported in any of the 2016 samples, the same results as 2015, 2014, and 5YA.
- The absence of heat damage likely was due in part to fresh samples coming directly from farm to elevator with minimal prior drying.

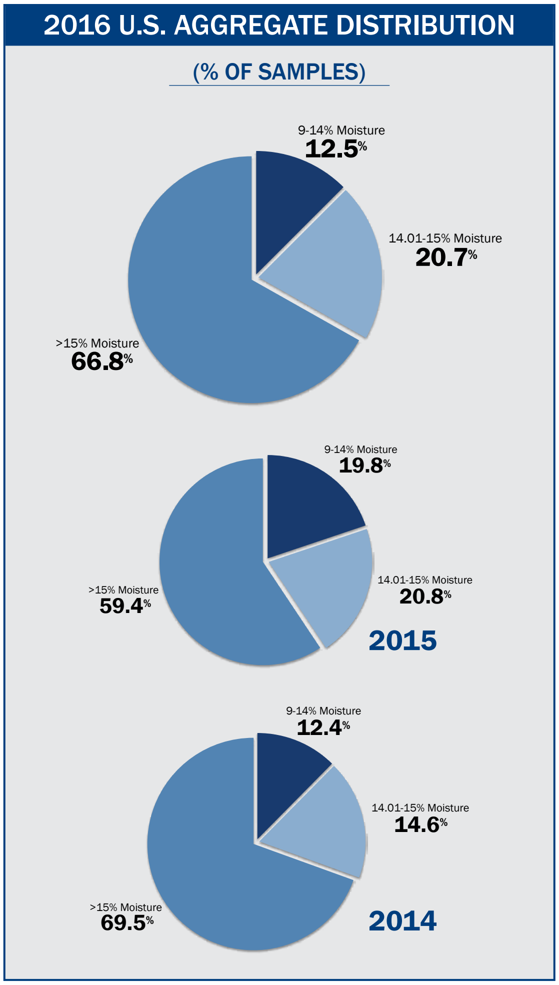
| U.S. Grade Heat Damage Maximum Limits |
|---|
| No. 1: 0.1% |
| No. 2: 0.2% |
| No. 3: 0.5% |

## B. MOISTURE

Moisture content is reported on official grade certificates, and maximum moisture content is usually specified in the contract. However, moisture does not determine which numerical grade will be assigned to the sample. Moisture content is important because it affects the amount of dry matter being sold and purchased. Moisture content is also an indicator of whether a need exists for drying, has potential implications for storability, and affects test weight. Higher moisture content at harvest increases the chance of kernel damage during harvesting and drying. Moisture content and the amount of drying required will also affect stress cracks, breakage, and germination. Extremely wet grain may be a precursor to high mold damage later in storage or transport. While the weather during the growing season affects yield, grain composition, and the development of the grain kernels, grain harvest moisture is influenced largely by crop maturation, the timing of harvest, and harvest weather conditions. General moisture storage guidelines suggest that 14% is the maximum moisture content for storage up to 6 to 12 months for good quality, clean corn under aerated storage under typical U.S. corn-belt conditions; and 13% or lower moisture content is recommended for storage of more than one year[1].

### *Results*

- The average U.S. Aggregate moisture content recorded at the elevator in the 2016 samples was 16.1%, which was higher than 2015 (15.7%), lower than 2014 (16.6%), and the same as 5YA (16.1%).
- U.S. Aggregate moisture standard deviation in 2016 (1.47%) was lower than in 2015 (1.53%), 2014 (1.84%), and 5YA (1.78%), indicating less variability in the 2016 samples than in prior years.
- The range in moisture content values in 2016 (11.2 to 23.7%) was the same as 2015 (11.0 to 23.5%), but less than 2014 (10.9 to 29.9%).
- The 2016 moisture values were distributed with 33.1%[2] of the samples containing 15% or less moisture. Fifteen percent is the base moisture used by most elevators for discounts and is a level considered safe for storage for short periods during low wintertime temperatures. There were more high moisture samples in the 2016 crop than in the 2015 crop, with 28.4% of the samples containing more than 17% moisture,




[1]*WPS-13. 1988. Grain drying, handling and storage handbook. Midwest Plan Service No. 13. Iowa State University, Ames, IA 50011.*

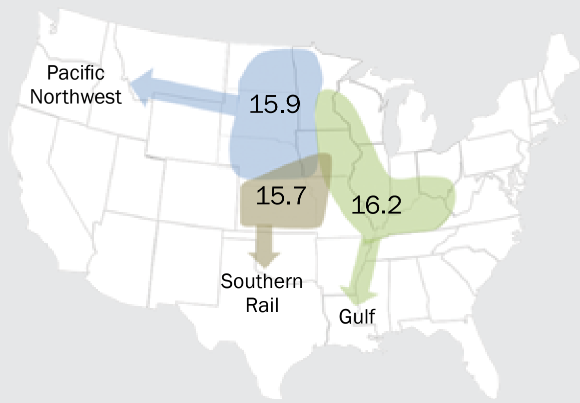
[2]*The pie chart and the histogram show that 33.2% and 33.1%, respectively, of the samples contained 15% or less moisture. This difference is solely due to rounding.*

compared to 19% in 2015 and 37% in 2014. This distribution indicates more drying will be required in 2016 than in 2015, but less than in 2014.

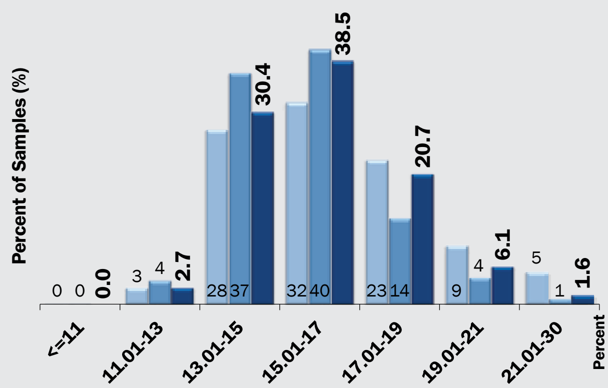
- In the 2016 crop, 12.5% of the samples contained 14% or less moisture compared to 19.8% in 2015 and 12.4% in 2014. Moisture content values of 14% and below are generally considered a safe level for longer–term storage and transport.
- The average moisture content for corn from the Gulf ECA (16.2%) was higher than the Pacific Northwest (15.9%) and the Southern Rail (15.7%) ECAs.
- Average moisture levels for the Gulf ECA were highest or tied for highest among all ECAs for 2016, 2015, 2014, and 5YA. Samples from the Gulf usually contain higher moisture content values as a result of weather and harvest conditions.
- Because of higher moistures in 2016 than in 2015, and higher total damage levels in 2016 than in previous years, care should be taken to monitor and maintain moisture levels sufficiently low to prevent possible future mold growth.

## MOISTURE (%)

### EXPORT CATCHMENT AREA AVERAGE




### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 16.1 | 1.47 |
| 2015 | 15.7 | 1.53 |
| 2014 | 16.6 | 1.84 |

## SUMMARY: GRADE FACTORS AND MOISTURE

| | 2016 Harvest | | | | | 2015 Harvest | | | 2014 Harvest | | | 5 Year Avg. (2011-2015) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | **U.S. Aggregate** | | | **U.S. Aggregate** | | | **U.S. Aggregate** | |
| Test Weight (lb/bu) | 624 | 58.3 | 1.22 | 51.5 | 61.9 | 620 | 58.2 | 1.08 | 629 | 57.6* | 1.34 | 58.1 | 1.33 |
| Test Weight (kg/hl) | 624 | 75.0 | 1.57 | 66.3 | 79.7 | 620 | 74.9 | 1.38 | 629 | 74.2* | 1.72 | 74.8 | 1.71 |
| BCFM (%) | 624 | 0.7 | 0.45 | 0.0 | 4.0 | 620 | 0.8* | 0.61 | 629 | 0.8* | 0.50 | 0.8 | 0.58 |
| Broken Corn (%) | 624 | 0.5 | 0.34 | 0.0 | 3.8 | 620 | 0.6* | 0.42 | 629 | 0.6* | 0.36 | 0.7 | 0.44 |
| Foreign Material (%) | 624 | 0.1 | 0.16 | 0.0 | 1.6 | 620 | 0.2* | 0.27 | 629 | 0.2* | 0.19 | 0.2 | 0.22 |
| Total Damage (%) | 624 | 2.6 | 1.61 | 0.0 | 23.1 | 620 | 1.4* | 1.00 | 629 | 1.7* | 1.36 | 1.2 | 0.97 |
| Heat Damage (%) | 624 | 0.0 | 0.00 | 0.0 | 0.0 | 620 | 0.0 | 0.00 | 629 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 624 | 16.1 | 1.47 | 11.2 | 23.7 | 620 | 15.7* | 1.53 | 629 | 16.6* | 1.84 | 16.1 | 1.78 |
| **Gulf** | | | | | | **Gulf** | | | **Gulf** | | | **Gulf** | |
| Test Weight (lb/bu) | 612 | 58.4 | 1.24 | 51.5 | 61.9 | 577 | 58.3 | 1.10 | 583 | 57.8* | 1.34 | 58.3 | 1.33 |
| Test Weight (kg/hl) | 612 | 75.1 | 1.59 | 66.3 | 79.7 | 577 | 75.0 | 1.41 | 583 | 74.5* | 1.73 | 75.0 | 1.71 |
| BCFM (%) | 612 | 0.7 | 0.45 | 0.0 | 4.0 | 577 | 0.8* | 0.63 | 583 | 0.8* | 0.48 | 0.8 | 0.57 |
| Broken Corn (%) | 612 | 0.5 | 0.34 | 0.0 | 3.8 | 577 | 0.5 | 0.41 | 583 | 0.6* | 0.37 | 0.6 | 0.43 |
| Foreign Material (%) | 612 | 0.2 | 0.17 | 0.0 | 1.6 | 577 | 0.2* | 0.30 | 583 | 0.2 | 0.15 | 0.2 | 0.21 |
| Total Damage (%) | 612 | 3.2 | 1.88 | 0.0 | 23.1 | 577 | 1.7* | 1.17 | 583 | 2.2* | 1.72 | 1.4 | 1.16 |
| Heat Damage (%) | 612 | 0.0 | 0.00 | 0.0 | 0.0 | 577 | 0.00 | 0.00 | 583 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 612 | 16.2 | 1.48 | 11.2 | 23.7 | 577 | 15.7* | 1.51 | 583 | 16.9* | 1.93 | 16.4 | 1.86 |
| **Pacific Northwest** | | | | | | **Pacific Northwest** | | | **Pacific Northwest** | | | **Pacific Northwest** | |
| Test Weight (lb/bu) | 301 | 58.0 | 1.19 | 52.2 | 61.9 | 329 | 57.9 | 1.02 | 262 | 56.6* | 1.36 | 57.4 | 1.34 |
| Test Weight (kg/hl) | 301 | 74.6 | 1.53 | 67.2 | 79.7 | 329 | 74.6 | 1.31 | 262 | 72.9* | 1.75 | 73.9 | 1.73 |
| BCFM (%) | 301 | 0.7 | 0.45 | 0.1 | 3.1 | 329 | 0.8* | 0.66 | 262 | 0.9* | 0.62 | 1.0 | 0.66 |
| Broken Corn (%) | 301 | 0.6 | 0.35 | 0.1 | 2.6 | 329 | 0.6 | 0.48 | 262 | 0.6 | 0.38 | 0.7 | 0.48 |
| Foreign Material (%) | 301 | 0.1 | 0.13 | 0.0 | 1.6 | 329 | 0.2* | 0.25 | 262 | 0.2* | 0.31 | 0.2 | 0.25 |
| Total Damage (%) | 301 | 1.0 | 0.75 | 0.0 | 14.0 | 329 | 0.5* | 0.53 | 262 | 0.4* | 0.39 | 0.5 | 0.46 |
| Heat Damage (%) | 301 | 0.0 | 0.00 | 0.0 | 0.0 | 329 | 0.00 | 0.00 | 262 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 301 | 15.9 | 1.50 | 11.2 | 20.7 | 329 | 15.7* | 1.55 | 262 | 16.1 | 1.75 | 15.3 | 1.62 |
| **Southern Rail** | | | | | | **Southern Rail** | | | **Southern Rail** | | | **Southern Rail** | |
| Test Weight (lb/bu) | 395 | 58.5 | 1.22 | 54.5 | 61.9 | 402 | 58.4* | 1.08 | 371 | 58.0* | 1.30 | 58.4 | 1.30 |
| Test Weight (kg/hl) | 395 | 75.4 | 1.57 | 70.2 | 79.7 | 402 | 75.1* | 1.38 | 371 | 74.7* | 1.67 | 75.1 | 1.68 |
| BCFM (%) | 395 | 0.7 | 0.43 | 0.1 | 3.1 | 402 | 0.7 | 0.46 | 371 | 0.7 | 0.45 | 0.9 | 0.55 |
| Broken Corn (%) | 395 | 0.5 | 0.31 | 0.1 | 2.5 | 402 | 0.5 | 0.32 | 371 | 0.5 | 0.31 | 0.7 | 0.41 |
| Foreign Material (%) | 395 | 0.2 | 0.16 | 0.0 | 1.6 | 402 | 0.2 | 0.20 | 371 | 0.2 | 0.20 | 0.2 | 0.20 |
| Total Damage (%) | 395 | 2.5 | 1.78 | 0.0 | 23.1 | 402 | 1.5* | 1.01 | 371 | 1.3* | 1.00 | 1.1 | 0.85 |
| Heat Damage (%) | 395 | 0.0 | 0.00 | 0.0 | 0.0 | 402 | 0.00 | 0.00 | 371 | 0.0 | 0.00 | 0.0 | 0.00 |
| Moisture (%) | 395 | 15.7 | 1.35 | 11.2 | 23.7 | 402 | 15.6 | 1.57 | 371 | 16.0* | 1.54 | 15.5 | 1.60 |

**Indicates averages in 2015 were significantly different from 2016, and 2014 averages were significantly different from 2016, based on a 2-tailed t-test at the 95% level of significance.*

*[1]Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

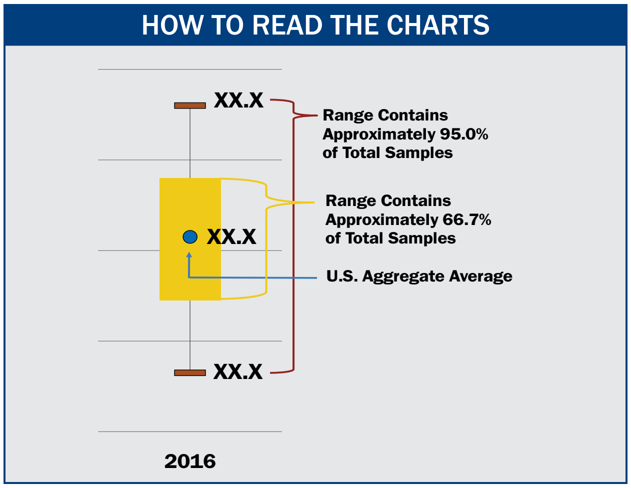
# C. CHEMICAL COMPOSITION

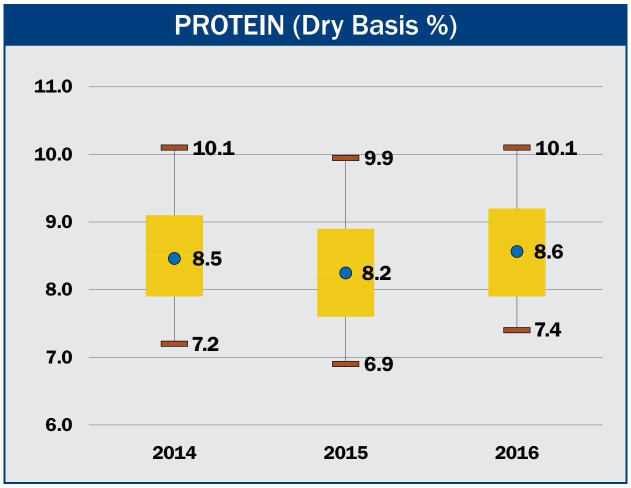
The chemical composition of corn consists primarily of protein, starch, and oil. While these attributes are not grade factors, they are of significant interest to end users. Chemical composition values provide additional information related to nutritional value for livestock and poultry feeding, for wet milling uses, and other processing uses of corn. Unlike many physical attributes, chemical composition values are not expected to change significantly during storage or transit.

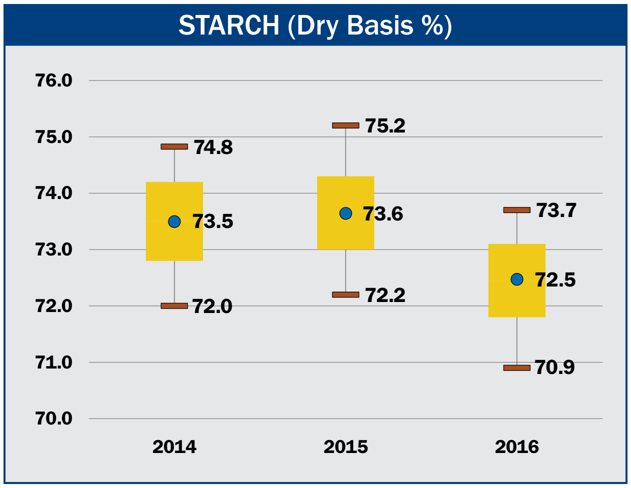
## SUMMARY: CHEMICAL COMPOSITION

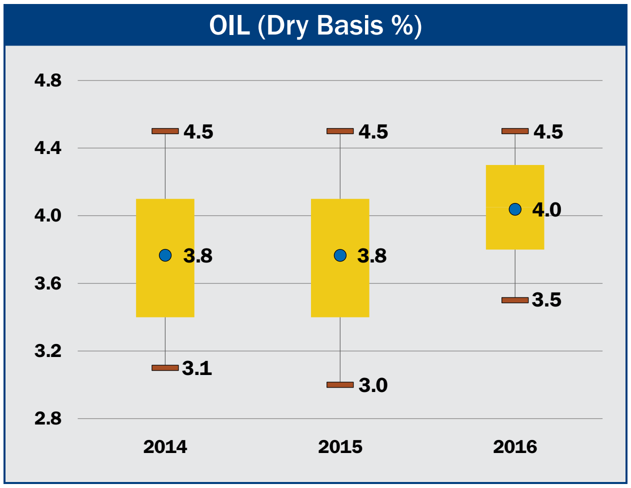
- The U.S. Aggregate protein concentration in 2016 (8.6% dry basis) was higher than 2015, slightly higher than 2014, but lower than 5YA.
- The Gulf ECA had lower protein concentrations than the other ECAs in 2016, 2015, 2014, and 5YA.
- Average U.S. Aggregate starch concentration in 2016 (72.5% dry basis) was lower than 2015, 2014, and 5YA.
- The Gulf ECA had higher starch concentrations than the Pacific Northwest and Southern Rail ECAs in 2016, 2015, 2014, and 5YA.
- Average U.S. Aggregate oil concentration (4.0% dry basis) in 2016 was higher than 2015, 2014, and 5YA.
- Chemical composition was less variable in 2016 than in the previous two years and 5YA (based on lower standard deviations for protein, starch, and oil).

U.S. GRAINS COUNCIL



## Protein

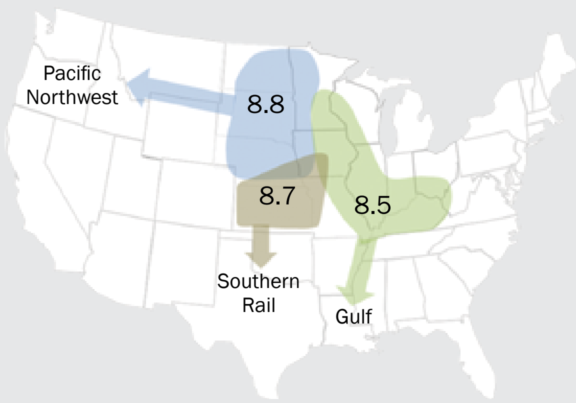
Protein is very important for poultry and livestock feeding by supplying essential sulfur-containing amino acids and helping to improve feed conversion efficiency. Protein concentration tends to decrease with decreased available soil nitrogen and in years with high crop yields. Protein is usually inversely related to starch concentration. Results are reported on a dry basis.

### *Results*

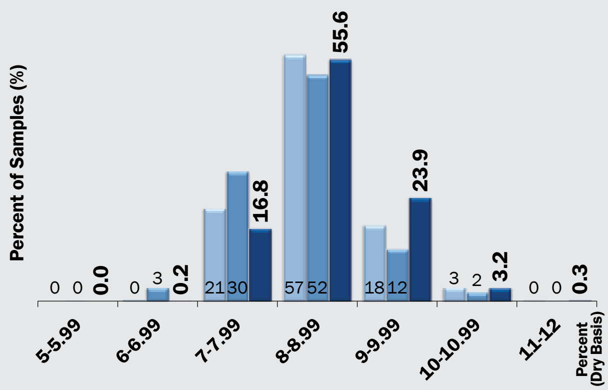
- U.S. Aggregate protein concentration in 2016 averaged 8.6%, higher than 2015 (8.2%) and 2014 (8.5%), but lower than 5YA (8.7%).
- U.S. Aggregate protein standard deviation in 2016 (0.50%) was slightly lower than 2015 (0.53%), 2014 (0.55%), and 5YA (0.60%).
- Protein concentration range in 2016 (6.8 to 11.7%) was similar to the ranges in 2015 (5.6 to 11.3%) and 2014 (6.4 to 11.3%).
- Protein concentrations in 2016 were distributed with 17% below 8.0%, 55.6% between 8.0 and 8.99%, and 27.4% at or above 9.0%. The protein distribution in 2016 shows fewer samples with low levels of protein than in 2015 or 2014.
- Protein concentration averages for Gulf, Pacific Northwest, and Southern Rail ECAs were 8.5%, 8.8%, and 8.7%, respectively. The Gulf ECA had the lowest protein for 2016, 2015, 2014, and 5YA.

**PROTEIN (%)**

**EXPORT CATCHMENT AREA AVERAGE**

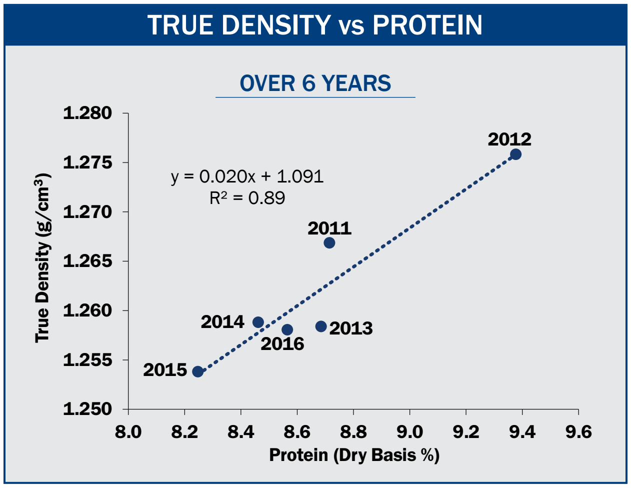



**U.S. AGGREGATE**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 8.6 | 0.50 |
| 2015 | 8.2 | 0.53 |
| 2014 | 8.5 | 0.55 |

- Based on U.S. Aggregate averages over the past six years, as protein concentration increases, true density increases (resulting in a correlation coefficient of 0.94), as shown in the figure to the right. Protein concentration appears to be lower in years with lower true density (2015) and higher in years with higher true density (2012).




## Starch

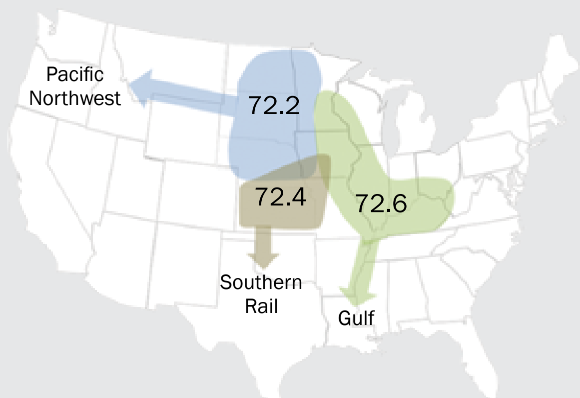
Starch is an important factor for corn used by wet millers and dry-grind ethanol manufacturers. High starch concentration is often indicative of good kernel growing/filling conditions and reasonably moderate kernel densities. Starch is usually inversely related to protein concentration. Results are reported on a dry basis.

### *Results*

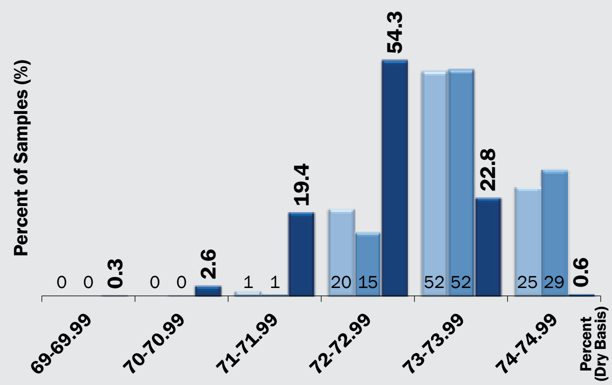
- Average U.S. Aggregate starch concentration (72.5%) in 2016 was lower than 2015 (73.6%), 2014 (73.5%), and 5YA (73.4%).
- U.S. Aggregate starch standard deviation in 2016 (0.59%) was slightly lower than 2015 (0.61%), 2014 (0.63%), and 5YA (0.64%).
- Starch concentration range in 2016 (69.2 to 74.3%) was similar to 2015 (70.5 to 76.3%) and 2014 (71.7 to 76.1%).
- Starch concentrations in 2016 were distributed with 22.3% of the samples below 72.0%, 54.3% between 72.0 and 72.99%, and 23.4% at 73.0% and higher. The distribution shows more samples had lower levels of starch in 2016 than in 2015 and 2014. The lower concentrations of starch in 2016 were likely due in part to higher protein concentrations in 2016.

**STARCH (%)**

**EXPORT CATCHMENT AREA AVERAGE**

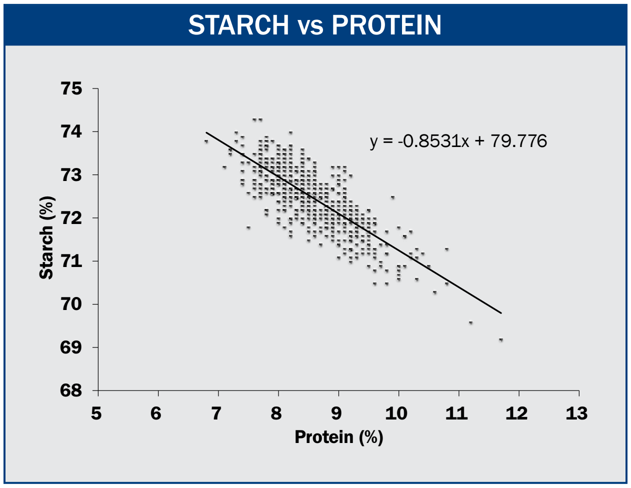



**U.S. AGGREGATE**




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 72.5 | 0.59 |
| 2015 | 73.6 | 0.61 |
| 2014 | 73.5 | 0.63 |

- Starch concentration averages for the Gulf, Pacific Northwest, and Southern Rail ECAs were 72.6%, 72.2%, and 72.4%, respectively. Starch concentration averages were highest in the Gulf ECA in 2016, 2015, 2014, and 5YA. Thus, the Gulf ECA had the highest starch and lowest protein in 2016, 2015, 2014, and 5YA.
- Since starch and protein are the two largest components in corn, when the percentage of one goes up, the other usually goes down. This relationship is illustrated in the adjacent figure showing a negative correlation (-0.79) between starch and protein.




## Oil

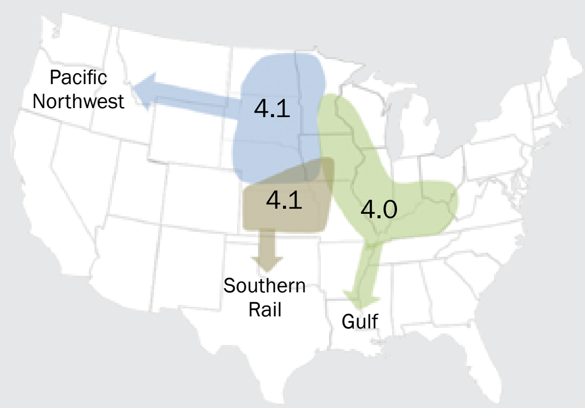
Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilized, and provides certain essential fatty acids. Oil is also an important co-product of corn wet and dry milling. Results are reported on a dry basis.

### *Results*

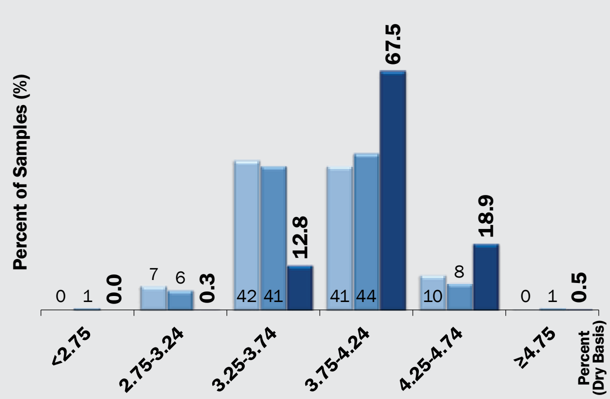
- Average U.S. Aggregate oil concentration (4.0%) in 2016 was higher than 2015 and 2014 (both 3.8%), and 5YA (3.7%).
- U.S. Aggregate oil standard deviation in 2016 (0.23%) was lower than 2015 (0.30%), 2014 (0.31%), and 5YA (0.32%).
- Oil concentration range in 2016 (3.2 to 4.9%) was narrower than 2015 (2.5 to 5.4%) and 2014 (2.8 to 5.0%).
- Oil concentrations in 2016 were distributed with 13.1% of the samples at 3.74% or lower, 67.5% of samples at 3.75 to 4.24%, and 19.4% at 4.25% and higher.
- Oil concentration averages for Gulf, Pacific Northwest, and Southern Rail ECAs were 4.0%, 4.1%, and 4.1%, respectively.

**OIL (%)**

EXPORT CATCHMENT AREA AVERAGE




U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 4.0 | 0.23 |
| 2015 | 3.8 | 0.30 |
| 2014 | 3.8 | 0.31 |

U.S. GRAINS COUNCIL

## SUMMARY: CHEMICAL FACTORS

| | 2016 Harvest | | | | | 2015 Harvest | | | 2014 Harvest | | | 5 Year Avg. (2011-2015) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | **U.S. Aggregate** | | | **U.S. Aggregate** | | | **U.S. Aggregate** | |
| Protein (Dry Basis %) | 624 | 8.6 | 0.50 | 6.8 | 11.7 | 620 | 8.2* | 0.53 | 629 | 8.5* | 0.55 | 8.7 | 0.60 |
| Starch (Dry Basis %) | 624 | 72.5 | 0.59 | 69.2 | 74.3 | 620 | 73.6* | 0.61 | 629 | 73.5* | 0.63 | 73.4 | 0.64 |
| Oil (Dry Basis %) | 624 | 4.0 | 0.23 | 3.2 | 4.9 | 620 | 3.8* | 0.30 | 629 | 3.8* | 0.31 | 3.7 | 0.32 |
| **Gulf** | | | | | | **Gulf** | | | **Gulf** | | | **Gulf** | |
| Protein (Dry Basis %) | 612 | 8.5 | 0.48 | 6.8 | 11.7 | 577 | 8.1* | 0.52 | 583 | 8.4* | 0.55 | 8.6 | 0.60 |
| Starch (Dry Basis %) | 612 | 72.6 | 0.59 | 69.2 | 74.3 | 577 | 73.7* | 0.62 | 583 | 73.6* | 0.64 | 73.5 | 0.65 |
| Oil (Dry Basis %) | 612 | 4.0 | 0.24 | 3.2 | 4.9 | 577 | 3.8* | 0.32 | 583 | 3.8* | 0.32 | 3.8 | 0.33 |
| **Pacific Northwest** | | | | | | **Pacific Northwest** | | | **Pacific Northwest** | | | **Pacific Northwest** | |
| Protein (Dry Basis %) | 301 | 8.8 | 0.55 | 7.3 | 11.7 | 329 | 8.7* | 0.58 | 262 | 8.7 | 0.56 | 8.9 | 0.60 |
| Starch (Dry Basis %) | 301 | 72.2 | 0.60 | 69.2 | 74.3 | 329 | 73.5* | 0.60 | 262 | 73.4* | 0.60 | 73.3 | 0.60 |
| Oil (Dry Basis %) | 301 | 4.1 | 0.22 | 3.2 | 4.9 | 329 | 3.7* | 0.28 | 262 | 3.6* | 0.29 | 3.6 | 0.29 |
| **Southern Rail** | | | | | | **Southern Rail** | | | **Southern Rail** | | | **Southern Rail** | |
| Protein (Dry Basis %) | 395 | 8.7 | 0.51 | 6.8 | 11.7 | 402 | 8.3* | 0.48 | 371 | 8.6 | 0.57 | 8.9 | 0.62 |
| Starch (Dry Basis %) | 395 | 72.4 | 0.59 | 69.2 | 74.3 | 402 | 73.5* | 0.60 | 371 | 73.4* | 0.60 | 73.2 | 0.63 |
| Oil (Dry Basis %) | 395 | 4.1 | 0.23 | 3.2 | 4.9 | 402 | 3.8* | 0.30 | 371 | 3.7* | 0.28 | 3.7 | 0.32 |

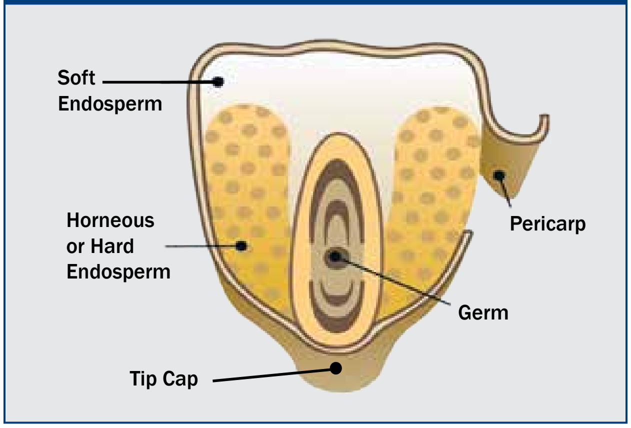
**Indicates averages in 2015 were significantly different from 2016, and 2014 averages were significantly different from 2016, based on a 2-tailed t-test at the 95% level of significance.*

*[1]Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

# D. PHYSICAL FACTORS

Physical factors are other quality attributes that are neither grade factors nor chemical composition. Physical factors include stress cracks, kernel weight, kernel volume and true density, percent whole kernels, and percent horneous (hard) endosperm. Tests for these physical factors provide additional information about the processing characteristics of corn for various uses, as well as corn's storability and potential for breakage in handling. These quality attributes are influenced by the physical composition of the corn kernel, which is in turn affected by genetics and growing and handling conditions. Corn kernels are made up of four parts: the germ or embryo, the tip cap, the pericarp or outer covering, and the endosperm. The endosperm represents about 82% of the kernel, and consists of soft (also referred to as floury or opaque) endosperm and of horneous (also called hard or vitreous) endosperm, as shown above. The endosperm contains primarily starch and protein, the germ contains oil and some proteins, and the pericarp and tip cap are mostly fiber.

CORN KERNEL

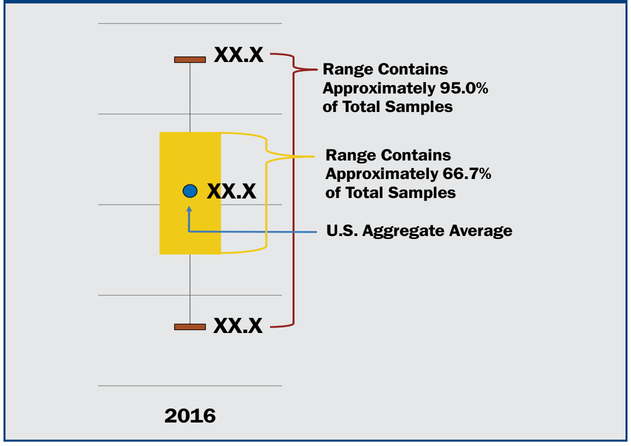



*Source: Adapted from Corn Refiners Association, 2011*

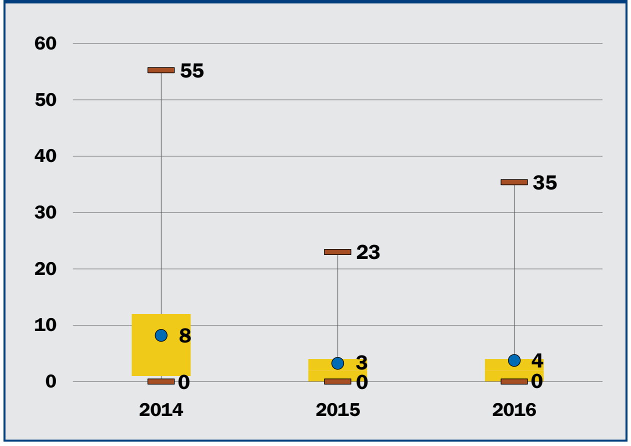
## SUMMARY: PHYSICAL FACTORS

- Average U.S. Aggregate stress cracks (4%) and stress crack index (SCI) (8.4) were slightly higher than 2015, but lower than 2014 and 5YA, indicating corn's susceptibility to breakage should be similar to last year, but below 2014 and 5YA.
- Among the ECAs, the Southern Rail ECA had the lowest SCI average in 2016, 2015, 2014, and 5YA. The Southern Rail also had the lowest stress cracks averages in 2016 and 5YA.
- Average U.S. Aggregate 100-k weight (35.20 g) in 2016 was higher than 2015, 2014, and 5YA.
- Average U.S. Aggregate kernel volume (0.28 $cm^3$) in 2016 was higher than 2015, 2014, and 5YA. There was also a higher percentage of large kernels in 2016, compared to the previous two years.
- The Pacific Northwest ECA had the lowest kernel volume average and lowest 100-k weight average of the ECAs in 2016, 2015, 2014, and 5YA.
- U.S. Aggregate kernel true density averaged 1.258 $g/cm^3$ in 2016, which was higher than 2015, similar to 2014, but lower than 5YA. Over the past six years, true densities have tended to be higher in years with higher protein.
- True density kernel distributions above 1.275 $g/cm^3$ in 2016 indicate slightly softer corn in 2016 and 2015 than in 2014. Of the ECAs, the Pacific Northwest had the lowest true density and lowest test weights in 2016, 2015, 2014, and 5YA.
- U.S. Aggregate whole kernels averaged 95.2% in 2016, higher than 2015, 2014, and 5YA.
- There was a higher percentage of whole kernels in 2016 and 2015 than in 2014. The relatively high percentages of whole kernels and low stress crack percentages indicate that the 2016 corn crop should handle well with minimal breakage.
- Average U.S. Aggregate horneous (hard) endosperm (79%) was same as 2015, and lower than 2014 and 5YA. The distributions of horneous endosperm percentages indicate a higher percentage of corn samples with soft endosperm in 2016 and 2015 than in 2014.
- Horneous endosperm and true density appear to change in the same direction, with higher values in a drought year, such as 2012, and lower values in higher-yielding years, such as 2016 and 2015.

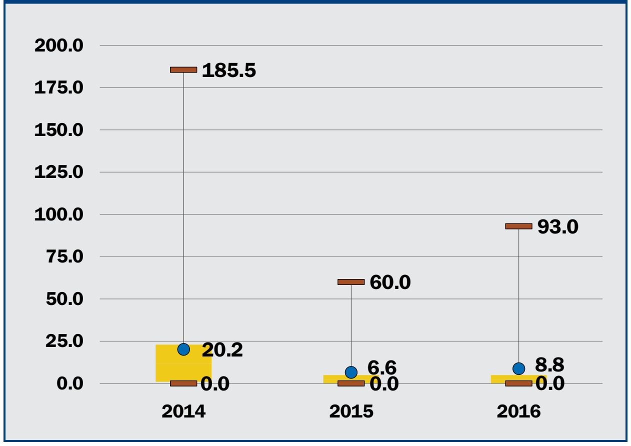
## HOW TO READ THE CHARTS



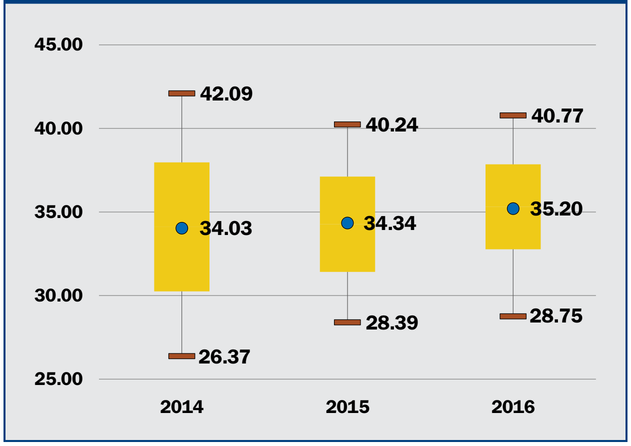

## STRESS CRACKS (%)

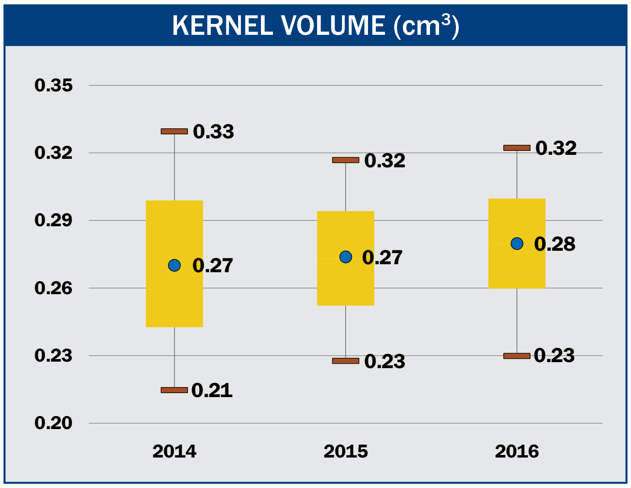


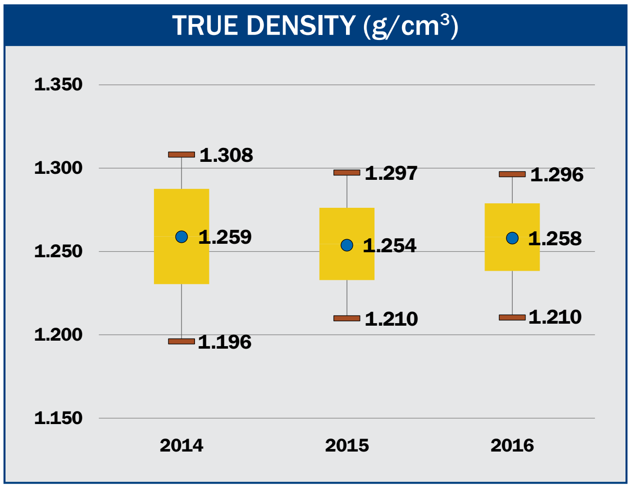

## STRESS CRACK INDEX

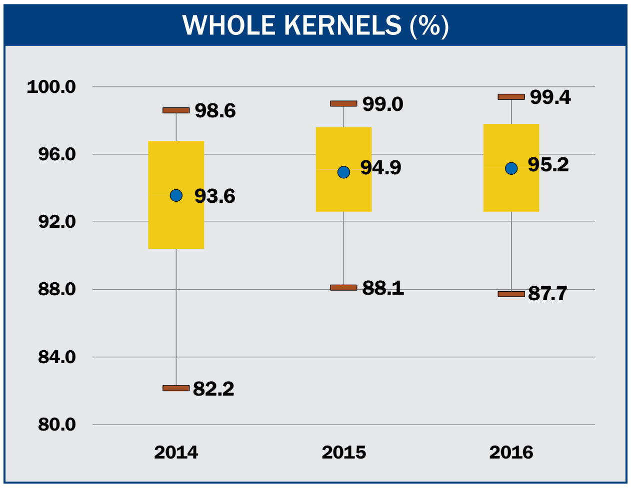


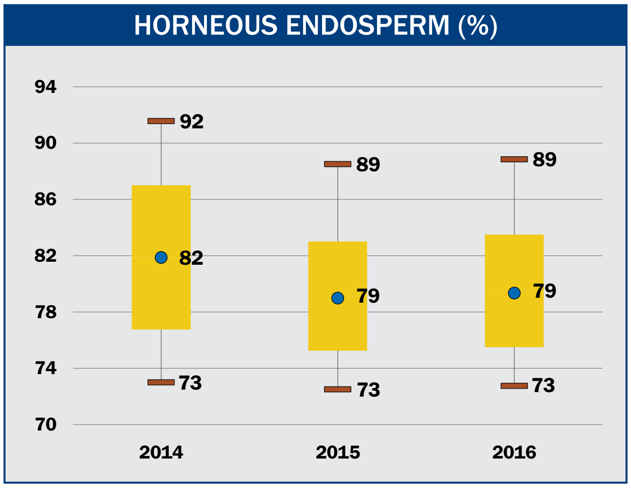

## 100-KERNEL WEIGHT (g)




KERNEL VOLUME (cm3)
0.35
0.32
0.29
0.26
0.23
0.20
0.33
0.27
0.21
0.32
0.27
0.23
0.32
0.28
0.23
2014
2015
2016


TRUE DENSITY (g/cm3)
1.350
1.300
1.250
1.200
1.150
1.308
1.259
1.196
1.297
1.254
1.210
1.296
1.258
1.210
2014
2015
2016


WHOLE KERNELS (%)
100.0
96.0
92.0
88.0
84.0
80.0
98.6
93.6
82.2
99.0
94.9
88.1
99.4
95.2
87.7
2014
2015
2016


HORNEOUS ENDOSPERM (%)
94
90
86
82
78
74
70
92
82
73
89
79
73
89
79
73
2014
2015
2016

## Stress Cracks

Stress cracks are internal fissures in the horneous (hard) endosperm of a corn kernel. The pericarp (or outer covering) of a stress-cracked kernel is typically not damaged, so the kernel may appear unaffected at first glance, even if stress cracks are present.

The cause of stress cracks is pressure buildup due to moisture and temperature gradients within the kernel's horneous endosperm. This can be likened to the internal cracks that appear when an ice cube is dropped into a lukewarm beverage. The internal stresses do not build up as much in the soft, floury endosperm as in the hard, horneous endosperm; therefore, corn with a higher percentage of horneous endosperm is more susceptible to stress cracking than softer grain. A kernel may vary in severity of stress cracking and can have one, two, or multiple stress cracks. The most common cause of stress cracks is high-temperature drying that rapidly removes moisture. The impact of high levels of stress cracks on various uses includes:

- General: Increased susceptibility to breakage during handling. This may lead to processors needing to remove more broken corn during cleaning operations, and a possible reduction in grade and/or value.
- Wet Milling: Lower starch yields due to the increased difficulty in separating starch and protein. Stress cracks may also alter steeping requirements.
- Dry Milling: Lower yield of large flaking grits (the prime product of many dry milling operations).
- Alkaline Cooking: Non-uniform water absorption leading to overcooking or undercooking, which affects the process balance.

Growing conditions will affect crop maturity, timeliness of harvest, and the need for artificial drying, which will influence the degree of stress cracking found from region to region. For example, late maturity or late harvest caused by weather-related factors, such as rain-delayed planting or cool temperatures, may increase the need for artificial drying, thus potentially increasing the occurrence of stress cracks.

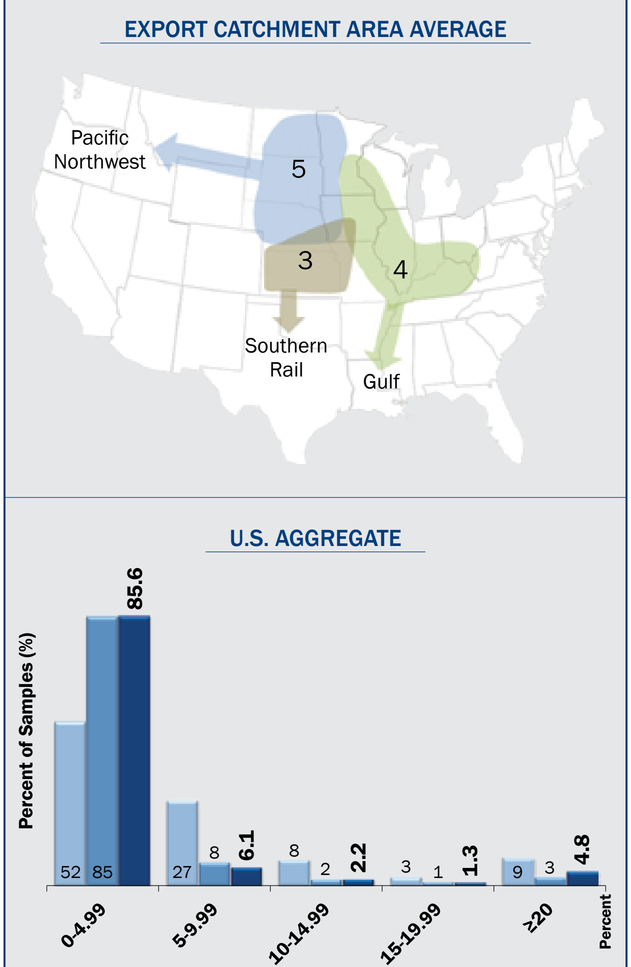
Stress crack measurements include "stress cracks" (the percentage of kernels with at least one crack) and stress crack index (SCI), which is the weighted average of single, double, and multiple stress cracks. "Stress cracks" measures only the number of kernels with stress cracks, whereas SCI shows the severity of stress cracking. For example, if half the kernels have only single stress cracks, "stress cracks" is 50% and the SCI is 50 (50 X 1). However, if half the kernels have multiple stress cracks (more than two cracks), indicating a higher potential for handling breakage, "stress cracks" remains at 50%, but the SCI becomes 250 (50 X 5). Lower values for "stress cracks" and the SCI are always more desirable. In years with high levels of stress cracks, the SCI provides valuable information because high SCI numbers (perhaps 300 to 500) indicate the sample had a very high percentage of multiple stress cracks. Multiple stress cracks are generally more detrimental to quality changes than single stress cracks.

U.S. GRAINS COUNCIL

## Results

- U.S. Aggregate stress cracks in 2016 averaged 4%, above 2015 (3%), but below 2014 (8%) and 5YA (5%).
- U.S. Aggregate stress cracks standard deviation (6%) in 2016 was higher than 2015 (5%), lower than 2014 (9%), but same as 5YA (6%).
- Stress cracks ranged from 0 to 84% in 2016, whereas the ranges were from 0 to 75% in 2015, and 0 to 100% in 2014.
- There was a high percentage of samples with less than 10% stress cracks in 2016 (91.7%), similar to 2015 (93%), and more than 2014 (79%). Also in 2016, 4.8% of the samples had stress cracks above 20%, which is similar to 2015 (3%), but lower than 2014 (9%).
- Stress crack distributions indicate that 2016 corn should have low susceptibility to breakage, similar to that found in 2015.
- Stress crack averages in 2016 for Gulf, Pacific Northwest, and Southern Rail ECAs were 4%, 5%, and 3%, respectively. Among all ECAs, the Southern Rail either had the lowest stress cracks or tied for lowest stress cracks in 2016, 2015, 2014, and 5YA.

**STRESS CRACKS (%)**

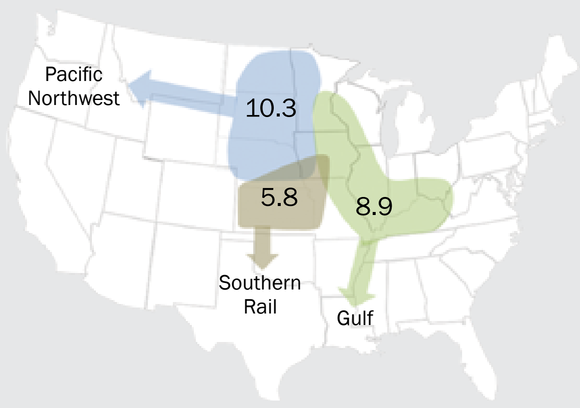



| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 4 | 6 |
| 2015 | 3 | 5 |
| 2014 | 8 | 9 |

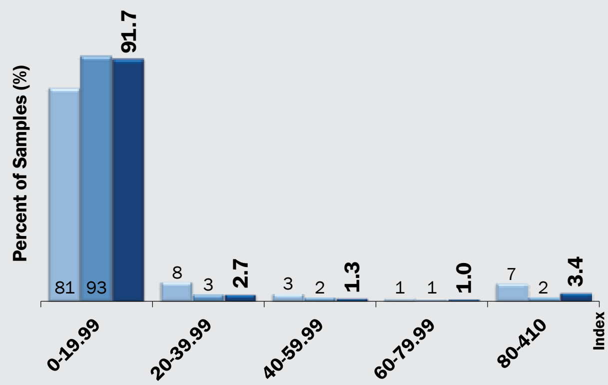
- U.S. Aggregate SCI in 2016 averaged 8.8, above 2015 (6.6), but below 2014 (20.2) and 5YA (12.7).
- U.S. Aggregate SCI was more variable in 2016 (standard deviation of 16.6) than in 2015 (11.7), but less than in 2014 (27.7) and 5YA (18.9).
- The 2016 SCI had a range of 0 to 268, wider than 2015 (0 to 180) and narrower than 2014 (0 to 410).
- Of the 2016 samples, 94.4% had SCI of less than 40, which is about the same as 2015 (96%) but higher than 2014 (89%) samples. Only 3.4% of the 2016 samples had SCI higher than 80, compared to 2% of the 2015 samples and 7% of the 2014 samples.
- SCI averages for the Gulf, Pacific Northwest, and Southern Rail ECAs were 8.9, 10.3, and 5.8, respectively.
- The Southern Rail ECA had the lowest SCI in 2016, 2015, 2014, and 5YA. The lower SCI found for the Southern Rail ECA is likely related to greater field drying potential typically found in the states that constitute the Southern Rail ECA.
- The high percentage of the 2016 crop having near 75% Good or Excellent crop growing conditions came with good maturation and grain filling, early harvest conditions, and favorable field drying weather. This led to less artificial drying needed than in wetter years and the relatively low stress cracks and SCI found in 2016.

## STRESS CRACK INDEX (SCI)

### EXPORT CATCHMENT AREA AVERAGE




### U.S. AGGREGATE




| | Avg | Std Dev |
|---|---|---|
| 2016 | 8.8 | 16.6 |
| 2015 | 6.6 | 11.7 |
| 2014 | 20.2 | 27.7 |

## 100-Kernel Weight

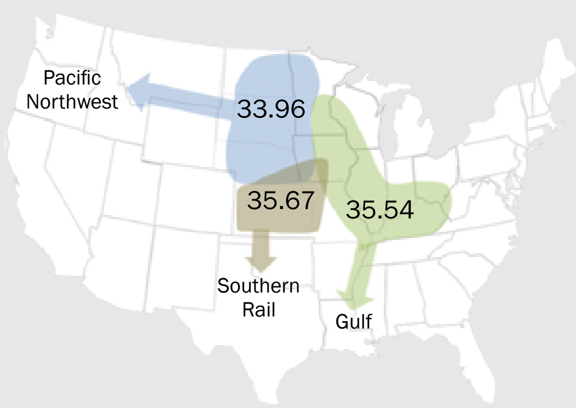
100-kernel (100-k) weight (reported in grams) indicates larger kernel size as 100-k weight increases. Kernel size affects drying rates. As kernel size increases, the volume-to-surface-area ratio becomes higher, and as the ratio gets higher, drying becomes slower. In addition, large, uniform-sized kernels often enable higher flaking grit yields in dry milling. Kernel weights tend to be higher for specialty varieties of corn that have high amounts of horneous (hard) endosperm.

### *Results*

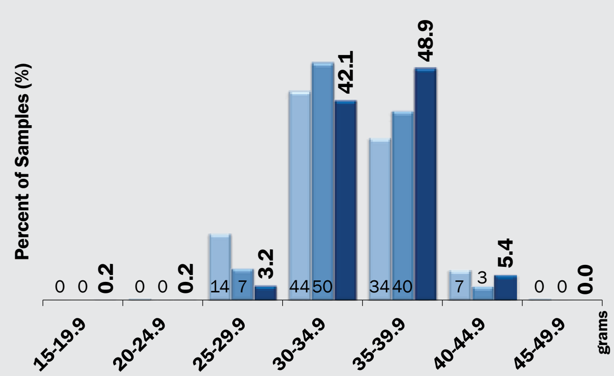
- U.S. Aggregate 100-k weight in 2016 averaged 35.20 g, higher than 2015 (34.34 g), 2014 (34.03 g), and 5YA (33.89 g).
- Variability in the 2016 U.S. Aggregate 100-k weight (standard deviation of 2.43 g) was same as 2015, but less than 2014 (2.83 g) and 5YA (2.71 g).
- 100-k weight range in 2016 (18.91 to 44.17 g) was greater than 2015 (24.90 to 45.64 g) and similar to 2014 (19.70 to 46.30 g).
- The 100-k weights in 2016 were distributed with 54.3% of the samples having 100-k weight of 35 g or greater, compared to 43% in 2015 and 41% in 2014. This distribution indicates a higher percentage of large kernels was found in 2016 than in the previous two years.
- Average 100-k weight was lowest for the Pacific Northwest ECA (33.96 g), compared to the Gulf (35.54 g) and Southern Rail (35.67 g) ECAs. The Pacific Northwest ECA also had the lowest 100-k weight in 2015, 2014, and 5YA.

**100-K WEIGHT (g)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (g) | Std Dev (g) |
|---|---|---|
| 2016 | 35.20 | 2.43 |
| 2015 | 34.34 | 2.43 |
| 2014 | 34.03 | 2.83 |

## Kernel Volume

Kernel volume in cubic centimeters (cm$^3$) is often indicative of growing conditions. If conditions are dry, kernels may be smaller than average. If drought hits later in the season, kernels may have lower fill.

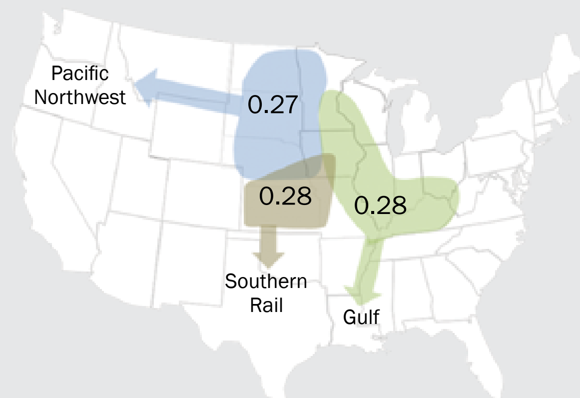
Small or round kernels are more difficult to degerm. Additionally, small kernels may lead to increased cleanout losses for processors and higher yields of fiber.

### *Results*

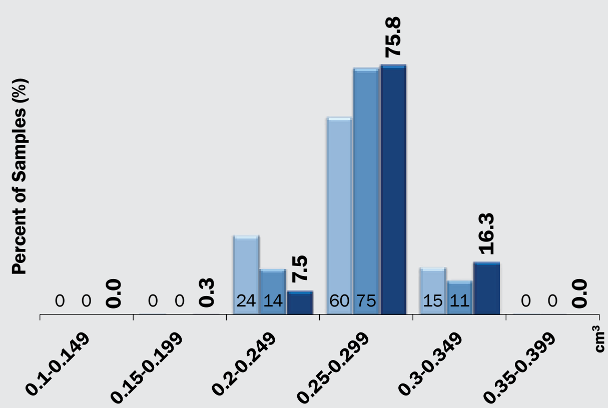
- U.S. Aggregate kernel volume averaged 0.28 cm$^3$ in 2016, which was higher than 0.27 cm$^3$ in 2015, 2014, and 5YA.
- Kernel volume variability was constant across the years. The standard deviation for U.S. Aggregate kernel volume was 0.02 cm$^3$ for 2016, 2015, 2014, and 5YA.
- Kernel volume range in 2016 (0.18 cm$^3$) was wider than in 2015 (0.15 cm$^3$) and slightly narrower than in 2014 (0.20 cm$^3$).
- The kernel volumes in 2016 were distributed so that 92.1% of the samples had kernel volumes of 0.25 cm$^3$ or greater, compared to 2015 (86%) and 2014 (75%). This distribution indicates there was a higher percentage of large kernels in 2016 compared to the previous two years.
- Kernel volume for the Gulf, Pacific Northwest, and Southern Rail ECAs averaged 0.28 cm$^3$, 0.27 cm$^3$, and 0.28 cm$^3$, respectively. The Pacific Northwest ECA had lower average kernel volume than the other two ECAs in 2016, 2015, 2014, and 5YA.

**KERNEL VOLUME (cm$^3$)**

**EXPORT CATCHMENT AREA AVERAGE**




**U.S. AGGREGATE**




| | Avg (cm$^3$) | Std Dev (cm$^3$) |
|---|---|---|
| 2016 | 0.28 | 0.02 |
| 2015 | 0.27 | 0.02 |
| 2014 | 0.27 | 0.02 |

## Kernel True Density

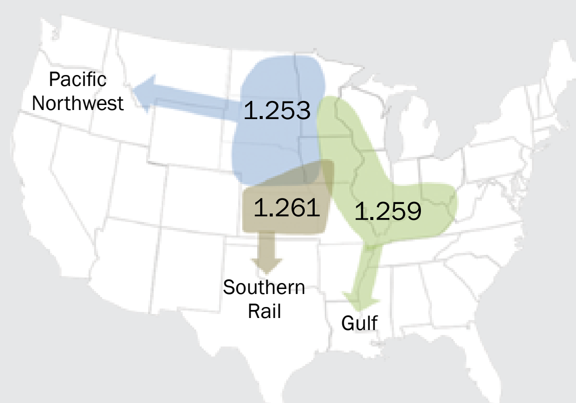
Kernel true density is calculated as the weight of a 100-k sample divided by the volume, or displacement, of those 100 kernels and is reported as grams per cubic centimeter (g/cm³). True density is a relative indicator of kernel hardness, which is useful for alkaline processors and dry millers. True density may be affected by the genetics of the corn hybrid and the growing environment. Corn with higher density is typically less susceptible to breakage in handling than lower density corn, but is also more at risk for the development of stress cracks if high-temperature drying is employed. True densities above 1.30 g/cm³ indicate very hard corn, which is typically desirable for dry milling and alkaline processing. True densities near the 1.275 g/cm³ level and below tend to be softer, but process well for wet milling and feed use.

### *Results*

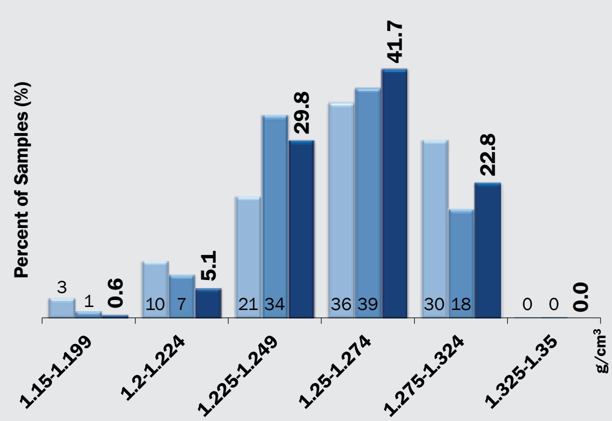
- Average U.S. Aggregate kernel true density (1.258 g/cm³) in 2016 was higher than 2015 (1.254 g/cm³), and lower than 2014 (1.259 g/cm³) and 5YA (1.263 g/cm³).
- Variability, based on the standard deviation, for true densities in 2016 (0.018 g/cm³) was higher than 2015 (0.017 g/cm³), but less than 2014 (0.020 g/cm³) and 5YA (0.019 g/cm³).
- True densities ranged from 1.162 to 1.320 g/cm³ in 2016, 1.166 to 1.327 g/cm³ in 2015, and 1.160 to 1.340 g/cm³ in 2014.
- About 23% of the 2016 samples had true densities at or above 1.275 g/cm³, compared to 18% of the samples in 2015 and 30% in 2014. Since corn with values above 1.275 g/cm³ is often considered to represent hard corn and corn with values below 1.275 g/cm³ is often considered to represent soft corn, this kernel distribution indicates slightly softer corn in 2016 and 2015 than in 2014.
- In 2016, kernel true densities for the Gulf, Pacific Northwest, and Southern Rail ECAs averaged 1.259 g/cm³, 1.253 g/cm³, and 1.261 g/cm³, respectively. Pacific Northwest average true density and test weight were lower than the other ECAs' values in 2016, 2015, 2014, and 5YA.

**KERNEL TRUE DENSITY (g/cm³)**

**EXPORT CATCHMENT AREA AVERAGE**



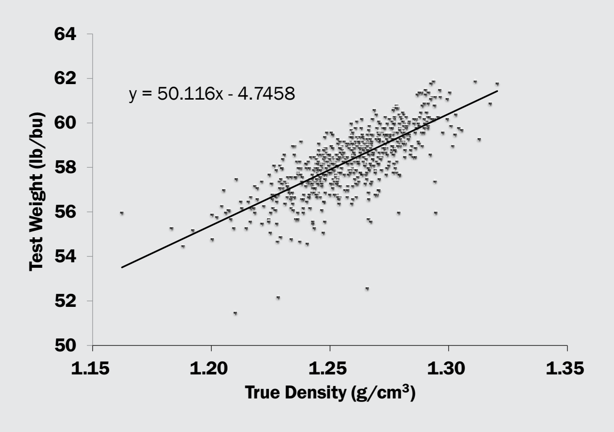

**U.S. AGGREGATE**




| | Avg (g/cm³) | Std Dev (g/cm³) |
|---|---|---|
| 2016 | 1.258 | 0.018 |
| 2015 | 1.254 | 0.017 |
| 2014 | 1.259 | 0.020 |

- Test weight, also known as bulk density, is based on the amount of mass contained in a quart cup. While test weight is influenced by true density, as shown in the adjacent figure (resulting in a correlation coefficient of 0.75), it is also affected by moisture content, pericarp damage (whole kernels), breakage, and other factors. In 2016, test weight was 58.3 lb/bu, which was similar to 58.2 lb/bu found in 2015 and higher than 57.6 lb/bu found in 2014.

**TEST WEIGHT vs TRUE DENSITY**




## Whole Kernels

Though the name suggests some inverse relationship between whole kernels and BCFM, the whole kernels test conveys different information than the broken corn portion of the BCFM test. Broken corn is defined solely by the size of the material. Whole kernels, as the name implies, is the percent of fully intact kernels in the sample with no pericarp damage or kernel pieces chipped away.

The exterior integrity of the corn kernel is very important for two key reasons. First, it affects water absorption for alkaline cooking and steeping operations. Kernel nicks or pericarp cracks allow water to enter the kernel faster than intact or whole kernels. Too much water uptake during cooking can result in loss of solubles, non-uniform cooking, expensive shutdown time, and/or products that do not meet specifications. Some companies pay contracted premiums for corn delivered above a specified level of whole kernels.

Second, intact whole kernels are less susceptible to storage molds and breakage in handling. While hard endosperm lends itself to preservation of more whole kernels than soft corn, the primary factor in delivering whole kernels is harvesting and handling. This begins with proper combine adjustment followed by the severity of kernel impacts due to conveyors and number of handlings required from the farm field to the end user. Each subsequent handling will generate additional breakage. Harvesting at higher moisture contents (e.g., greater than 25%) will usually lead to more pericarp damage to corn than harvesting at lower moisture levels.

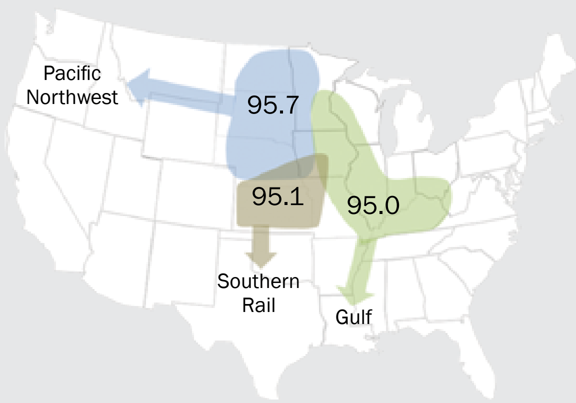
U.S. GRAINS COUNCIL

## *Results*

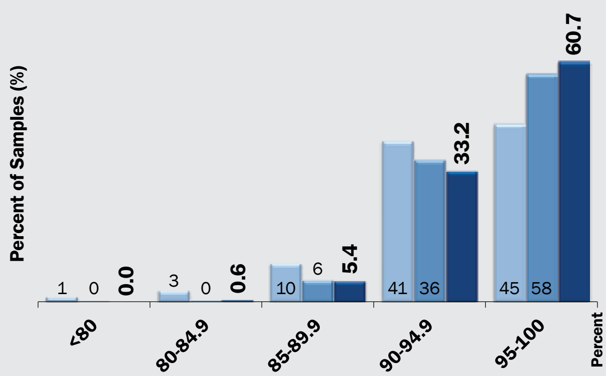
- U.S. Aggregate whole kernels averaged 95.2% in 2016, higher than 2015 (94.9%), 2014 (93.6%), and 5YA (93.8%).
- The whole kernel standard deviation (2.7%) was the same as 2015, but lower than 2014 (3.5%) and 5YA (3.4%).
- Whole kernel range in 2016 (19.4%) was lower than 2015 (21.4%) and 2014 (36.2%).
- Of the 2016 samples, 93.9% had 90% or higher whole kernels, compared to 2015 (94%) and 2014 (86%). This distribution indicates both 2016 and 2015 had a higher percentage of whole kernels in the samples than in 2014.
- Whole kernel averages for Gulf, Pacific North-west, and Southern Rail ECAs were 95.0%, 95.7%, and 95.1%, respectively.

### WHOLE KERNELS (%)

#### EXPORT CATCHMENT AREA AVERAGE




#### U.S. AGGREGATE




| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 95.2 | 2.7 |
| 2015 | 94.9 | 2.7 |
| 2014 | 93.6 | 3.5 |

## Horneous (Hard) Endosperm

The horneous (hard) endosperm test measures the percent of horneous or hard endosperm out of the total endosperm in a kernel, with a potential value from 70 to 100%. The greater the amount of horneous endosperm relative to soft endosperm, the harder the corn kernel is said to be. The degree of hardness is important depending on the type of processing. Hard corn is needed to produce high yields of large flaking grits in dry milling. Medium-high to medium hardness is desired for alkaline cooking. Moderate to soft hardness is used for wet milling and livestock feeding.

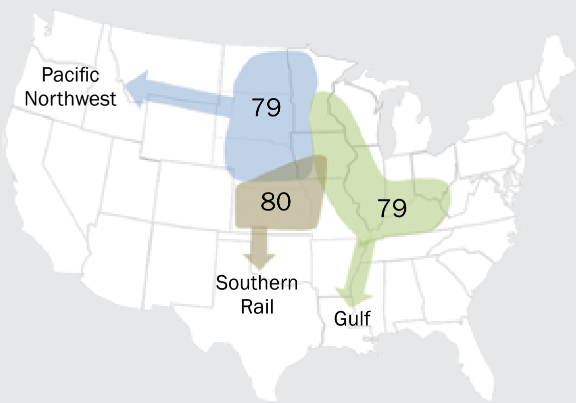
Hardness has been correlated to breakage susceptibility, feed utilization/efficiency, and starch digestibility. As a test of overall hardness, there is no good or bad value for horneous endosperm; there is only a preference by different end users for particular ranges. Many dry millers and alkaline cookers would like greater than 90% horneous endosperm, while wet millers and feeders would typically like values between 70 and 85%. However, there are certainly exceptions in user preference.

### *Results*

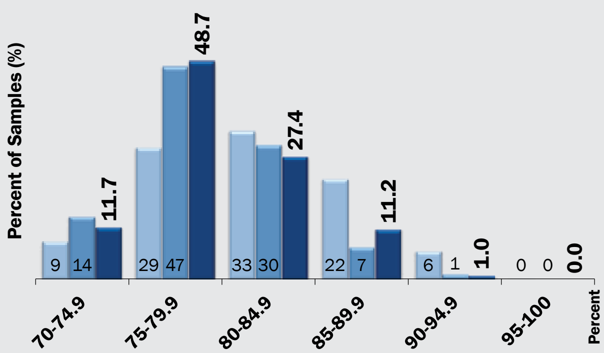
- Average U.S. Aggregate horneous endosperm (79%) in 2016 was same as 2015, and lower than 2014 (82%) and 5YA (83%).
- U.S. Aggregate standard deviation for horneous endosperm was 4%, higher than 2015 (3%), but same as 2014 and 5YA (both 4%).
- The 2016 horneous endosperm range (71 to 93%) was slightly lower than 2015 (71 to 95%) and 2014 (71 to 97%).
- Of the 2016 samples, 60.4% contained less than 80% horneous endosperm, which was similar to 2015 (61%) and much higher than 2014 (38%). This distribution indicates a higher percentage of corn samples with soft endosperm in 2016 and 2015 than in 2014.
- Average horneous endosperm was uniform across the Gulf, Pacific Northwest, and Southern Rail ECAs, with an average of 79%, 79%, and 80% for the three ECAs, respectively.
- The figure on the adjacent page shows a weak but positive relationship (a correlation coefficient of 0.70) between horneous endosperm and true density for the 2016 samples.
- The second figure shows the average U.S. Aggregate horneous endosperm and true density values over the past six years. This illustrates that average U.S. Aggregate horneous endosperm increases with true density (with a correlation coefficient of 0.88); thus, horneous endosperm tends to be higher in years when average true density is higher.

## HORNEOUS ENDOSPERM (%)

### EXPORT CATCHMENT AREA AVERAGE

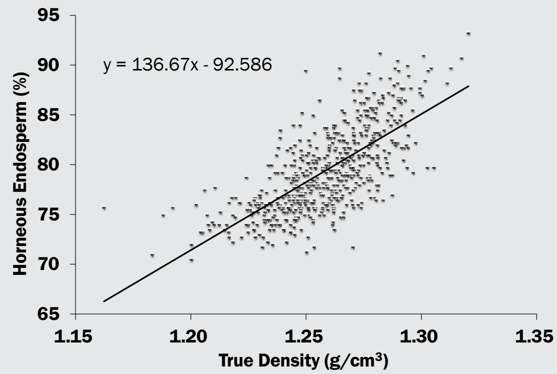



### U.S. AGGREGATE



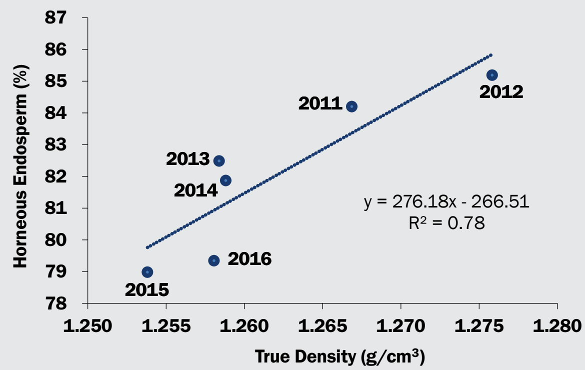

| | Avg (%) | Std Dev (%) |
|---|---|---|
| 2016 | 79 | 4 |
| 2015 | 79 | 3 |
| 2014 | 82 | 4 |

## HORNEOUS ENDOSPERM vs TRUE DENSITY




## HORNEOUS ENDOSPERM vs TRUE DENSITY

### OVER 6 YEARS



# SUMMARY: PHYSICAL FACTORS

| | 2016 Harvest | | | | | 2015 Harvest | | | 2014 Harvest | | | 5 Year Avg. (2011-2015) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Samples[1] | Avg. | Std. Dev. | Min. | Max. | No. of Samples[1] | Avg. | Std. Dev. | No. of Samples[1] | Avg. | Std. Dev. | Avg. | Std. Dev. |
| **U.S. Aggregate** | | | | | | **U.S. Aggregate** | | | **U.S. Aggregate** | | | **U.S. Aggregate** | |
| Stress Cracks (%)[2] | 624 | 4 | 6 | 0 | 84 | 620 | 3 | 5 | 629 | 8* | 9 | 5 | 6 |
| Stress Crack Index[2] | 624 | 8.8 | 16.6 | 0 | 268 | 620 | 6.6* | 11.7 | 629 | 20.2* | 27.7 | 12.7 | 18.9 |
| 100-Kernel Weight (g) | 624 | 35.20 | 2.43 | 18.91 | 44.17 | 620 | 34.34* | 2.43 | 629 | 34.03* | 2.83 | 33.89 | 2.71 |
| Kernel Volume ($cm^3$) | 624 | 0.28 | 0.02 | 0.16 | 0.34 | 620 | 0.27* | 0.02 | 629 | 0.27* | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 624 | 1.258 | 0.018 | 1.162 | 1.320 | 620 | 1.254* | 0.017 | 629 | 1.259 | 0.020 | 1.263 | 0.019 |
| Whole Kernels (%) | 624 | 95.2 | 2.7 | 80.6 | 100.0 | 620 | 94.9 | 2.7 | 629 | 93.6* | 3.5 | 93.8 | 3.4 |
| Horneous Endosperm (%) | 624 | 79 | 4 | 71 | 93 | 620 | 79 | 3 | 629 | 82* | 4 | 83 | 4 |
| **Gulf** | | | | | | **Gulf** | | | **Gulf** | | | **Gulf** | |
| Stress Cracks (%)[2] | 612 | 4 | 6 | 0 | 84 | 577 | 3 | 5 | 583 | 9* | 10 | 6 | 7 |
| Stress Crack Index[2] | 612 | 8.9 | 17.6 | 0 | 268 | 577 | 7.0* | 12.4 | 583 | 24.1* | 33.3 | 13.8 | 21.4 |
| 100-Kernel Weight (g) | 612 | 35.54 | 2.49 | 18.91 | 44.17 | 577 | 34.64* | 2.47 | 583 | 34.88* | 2.90 | 34.41 | 2.74 |
| Kernel Volume ($cm^3$) | 612 | 0.28 | 0.02 | 0.16 | 0.34 | 577 | 0.28* | 0.02 | 583 | 0.28* | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 612 | 1.259 | 0.018 | 1.162 | 1.320 | 577 | 1.255* | 0.017 | 583 | 1.262* | 0.020 | 1.265 | 0.019 |
| Whole Kernels (%) | 612 | 95.0 | 2.7 | 80.6 | 100.0 | 577 | 95.0 | 2.8 | 583 | 93.8* | 3.3 | 93.9 | 3.5 |
| Horneous Endosperm (%) | 612 | 79 | 4 | 71 | 93 | 577 | 79 | 3 | 583 | 82* | 4 | 83 | 4 |
| **Pacific Northwest** | | | | | | **Pacific Northwest** | | | **Pacific Northwest** | | | **Pacific Northwest** | |
| Stress Cracks (%)[2] | 301 | 5 | 7 | 0 | 84 | 329 | 3* | 4 | 262 | 6* | 6 | 5 | 5 |
| Stress Crack Index[2] | 301 | 10.3 | 17.5 | 0 | 268 | 329 | 6.6* | 11.9 | 262 | 12.8 | 17.1 | 12.1 | 15.6 |
| 100-Kernel Weight (g) | 301 | 33.96 | 2.21 | 23.98 | 44.17 | 329 | 33.08* | 2.29 | 262 | 30.92* | 2.57 | 31.93 | 2.53 |
| Kernel Volume ($cm^3$) | 301 | 0.27 | 0.02 | 0.19 | 0.34 | 329 | 0.26* | 0.02 | 262 | 0.25* | 0.02 | 0.25 | 0.02 |
| True Density ($g/cm^3$) | 301 | 1.253 | 0.016 | 1.162 | 1.317 | 329 | 1.249* | 0.017 | 262 | 1.246* | 0.021 | 1.253 | 0.019 |
| Whole Kernels (%) | 301 | 95.7 | 2.7 | 84.4 | 100.0 | 329 | 94.8* | 2.6 | 262 | 92.5* | 4.4 | 93.5 | 3.5 |
| Horneous Endosperm (%) | 301 | 79 | 3 | 71 | 91 | 329 | 79* | 3 | 262 | 81* | 4 | 82 | 4 |
| **Southern Rail** | | | | | | **Southern Rail** | | | **Southern Rail** | | | **Southern Rail** | |
| Stress Cracks (%)[2] | 395 | 3 | 4 | 0 | 62 | 402 | 3 | 3 | 371 | 6* | 6 | 4 | 4 |
| Stress Crack Index[2] | 395 | 5.8 | 11.0 | 0 | 205 | 402 | 4.7 | 8.2 | 371 | 11.4* | 15.3 | 7.6 | 10.7 |
| 100-Kernel Weight (g) | 395 | 35.67 | 2.50 | 25.93 | 44.17 | 402 | 35.09* | 2.49 | 371 | 34.47* | 2.83 | 34.21 | 2.81 |
| Kernel Volume ($cm^3$) | 395 | 0.28 | 0.02 | 0.21 | 0.34 | 402 | 0.28* | 0.02 | 371 | 0.27* | 0.02 | 0.27 | 0.02 |
| True Density ($g/cm^3$) | 395 | 1.261 | 0.018 | 1.183 | 1.317 | 402 | 1.255* | 0.017 | 371 | 1.263 | 0.019 | 1.267 | 0.018 |
| Whole Kernels (%) | 395 | 95.1 | 2.6 | 84.4 | 100.0 | 402 | 94.9 | 2.8 | 371 | 93.9* | 3.2 | 93.8 | 3.2 |
| Horneous Endosperm (%) | 395 | 80 | 4 | 71 | 91 | 402 | 79* | 3 | 371 | 82* | 4 | 83 | 4 |

**Indicates averages in 2015 were significantly different from 2016, and 2014 averages were significantly different from 2016, based on a 2-tailed t-test at the 95% level of significance.*

*[1]Due to the ECA results being composite statistics, the sum of the sample numbers from the three ECAs is greater than the U.S. Aggregate.*

*[2]The Relative ME for predicting the harvest population average exceeded ±10%.*

# E. MYCOTOXINS

Mycotoxins are toxic compounds produced by fungi that occur naturally in grains. When consumed at elevated levels, mycotoxins may cause sickness in humans and animals. While several mycotoxins have been found in corn grain, aflatoxins and DON (deoxynivalenol or vomitoxin) are considered to be two of the important mycotoxins.

As in the previous *Harvest Reports*, the 2016 harvest samples were tested for aflatoxins and DON for this year's report. Since the production of mycotoxins is heavily influenced by growing conditions, the objective of the *Harvest Report* is strictly to report on instances when aflatoxins or DON are detected in the corn crop at harvest. No specific levels of the mycotoxins are reported.

The *Harvest Report* review of mycotoxins is NOT intended to predict the presence or level at which mycotoxins might appear in U.S. corn exports. Due to the multiple stages of the U.S. grain merchandising channel and the laws and regulations guiding the industry, the levels at which mycotoxins appear in corn exports are less than what might first appear in the corn as it comes out of the field. In addition, this report is not meant to imply that this assessment will capture all the instances of mycotoxins across the 12 states or three Export Catchment Areas (ECAs) surveyed. The *Harvest Report's* results should be used only as one indicator of the potential for mycotoxin presence in the corn as the crop comes out of the field. As the Council accumulates several years of the *Harvest Reports*, year-to-year patterns of mycotoxin presence in corn at harvest will be seen. The *U.S. Grains Council 2016/2017 Corn Export Cargo Quality Report* will report corn quality at export points and will be a more accurate indication of mycotoxin presence in the 2016/2017 U.S. corn export shipments.

## Assessing the Presence of Aflatoxins and DON

At least 25% of the minimum number of samples (600) across the sampling area was proportionately collected and tested to assess the impact of the 2016 growing conditions on total aflatoxins and DON development in the U.S. corn crop. The sampling criteria, described in the "Survey and Statistical Analysis Methods" section, resulted in a total number of 177 samples tested for mycotoxins.

A threshold established by the U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) as the "Lower Conformance Level" (LCL) was used to determine whether or not a detectable level of the mycotoxin appeared in the sample. The LCLs for the FGIS-approved analytical kits and used for this 2016/2017 report were 5.0 parts per billion (ppb) for aflatoxins and 0.5 parts per million (ppm) for DON. The FGIS LCL was higher than the Limit of Detection (LOD) specified by the kit manufacturer of 2.5 ppb and 0.3 ppm for aflatoxin and DON, respectively. Details on the testing methodology employed in this study for the mycotoxins are in the "Testing Analysis Methods" section.

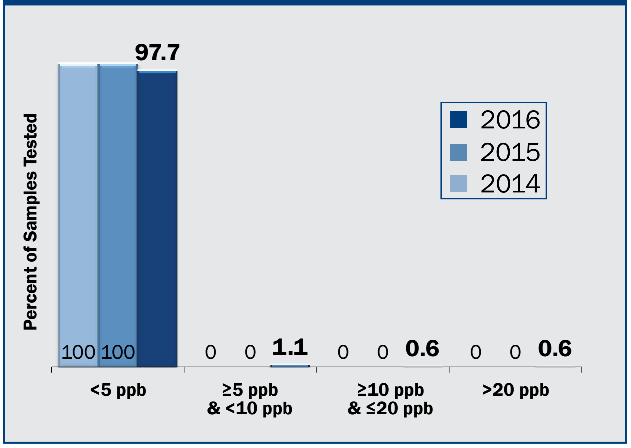
### *Results: Aflatoxins*

A total of 177 samples were analyzed for aflatoxins in 2016, compared to 185 and 182 samples tested for aflatoxins in 2015 and 2014, respectively. Results of the 2016 survey are as follows:

- One hundred seventy-three (173) samples, or 97.7% of the 177 samples, had no detectable levels of aflatoxins (below the FGIS LCL of 5.0 ppb). This is slightly below 2015 and 2014, where 100% of the samples tested had no detectable levels of aflatoxins in both years.
- Two samples (2), or 1.1% of the 177 samples, showed aflatoxin levels greater than or equal to 5 ppb, but less than 10 ppb.
- One sample (1), or 0.6% of the 177 samples, showed an aflatoxin level greater than or equal to 10 ppb, but less than or equal to the FDA action level of 20 ppb.
- One sample (1), or 0.6% of the 177 samples, showed an aflatoxin level greater than or equal to FDA action level of 20 ppb.
- These results denote that 176 samples, or 99.4% of the 177 sample test results in 2016, were below or equal to the FDA action level of 20 ppb, compared to 100% of the samples tested in both 2015 and 2014.

While the 2016 crop season had a slightly lower percentage of samples below the FGIS LCL of 5.0 ppb than 2015 and 2014, the high percentage of 2016 samples testing below the LCL may be due, in part, to favorable weather conditions in 2016 (see the "Crop and Weather Conditions" section for more information on the 2016 growing conditions). Most of the growing area received ample moisture during pollination and grain-fill in 2016, and the corn plants were not under stress as a result.

**AFLATOXINS TESTING RESULTS**



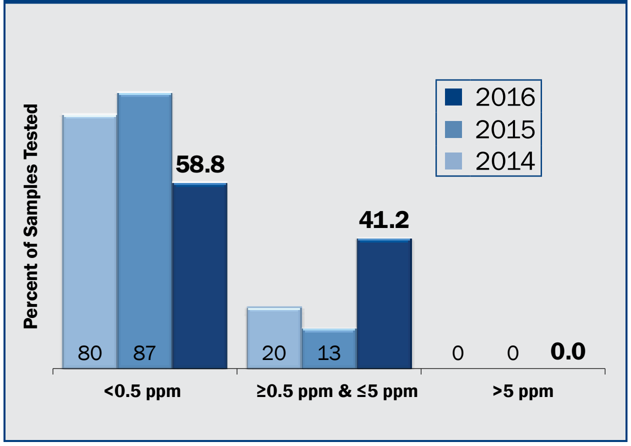
## Results: DON (Deoxynivalenol or Vomitoxin)

A total of 177 samples were analyzed collectively for DON in 2016, compared to 185 and 182 samples tested for DON in 2015 and 2014, respectively. Results of the 2016 survey are as follows:

- One hundred four (104) samples, or 58.8% of the 177 samples had no detectable levels of DON (below the FGIS LCL of 0.5 ppm).
- The 2016 percentage for samples that tested below 0.5 ppm (58.8%) was lower than 2015 (87%) and 2014 (80%).
- Seventy-three (73) samples, or 41.2% of the 177 samples, tested greater than or equal to 0.5 ppm, but less than or equal to the FDA advisory level of 5 ppm.
- All 177 samples, or 100%, tested below or equal to the FDA advisory level of 5 ppm, which was the same as was observed in 2015 and 2014.

While the samples in the 2016, 2015, and 2014 surveys were all below 5 ppm, the decrease in the percentage of samples below 0.5 ppm in 2016, compared to 2015 and 2014, may be attributed to wet weather conditions that were more conducive to DON development in 2016.

**DON TESTING RESULTS**



## Background: General

The levels at which fungi produce mycotoxins are impacted by the fungus type and the environmental conditions under which the corn is produced and stored. Because of these differences, mycotoxin production varies across the U.S. corn-producing areas and across years. In some years, the growing conditions across the corn-producing regions might not produce elevated levels of any mycotoxins. In other years, the environmental conditions in a particular area might be conducive to production of a particular mycotoxin to levels that impact the corn's use for human and livestock consumption. Humans and livestock are sensitive to mycotoxins at varying levels. As a result, the U.S. Food and Drug Administration (FDA) has issued action levels for aflatoxins and advisory levels for DON by intended use.

**Action levels** specify precise limits of contamination above which the agency is prepared to take regulatory action. Action levels are a signal to the industry that the FDA believes it has scientific data to support regulatory and/or court action if a toxin or contaminant is present at levels exceeding the action level, if the agency chooses to do so. If imports or domestic feed supplements are analyzed in accordance with valid methods and found to exceed applicable action levels, they are considered adulterated and may be seized and removed from interstate commerce by the FDA.

**Advisory levels** provide guidance to the industry concerning levels of a substance present in food or feed that are believed by the agency to provide an adequate margin of safety to protect human and animal health. While the FDA reserves the right to take regulatory enforcement action, enforcement is not the fundamental purpose of an advisory level.

A source of additional information is the National Grain and Feed Association (NGFA) guidance document titled "FDA Mycotoxin Regulatory Guidance" found at http://www.ngfa.org/wp-content/uploads/NGFAComplianceGuide-FDARegulatoryGuidancefor-Mycotoxins8-2011.pdf.

## Background: Aflatoxins

The most important type of mycotoxin associated with corn grain is aflatoxin. There are several types of aflatoxin produced by different species of *Aspergillus*, with the most prominent species being *A. flavus*. Growth of the fungus and aflatoxin contamination of grain can occur in the field prior to harvest or in storage. However, contamination prior to harvest is considered to cause most of the problems associated with aflatoxin. *A. flavus* grows well in hot, dry environmental conditions or where drought occurs over an extended period of time. It can be a serious problem in the southern United States where hot and dry conditions are more common. The fungus usually attacks only a few kernels on the ear and often penetrates kernels through wounds produced by insects. Under drought conditions, it also grows down silks into individual kernels.

There are four types of aflatoxin naturally found in foods – aflatoxins B1, B2, G1, and G2. These four aflatoxins are commonly referred to as "aflatoxins" or "total aflatoxins." Aflatoxin B1 is the most commonly found aflatoxin in food and feed and is also the most toxic. Research has shown that B1 is a potent, naturally-occurring carcinogen in animals, with a strong link to human cancer incidence. Additionally, dairy cattle will metabolize aflatoxin to a different form of aflatoxin called aflatoxin M1, which may accumulate in milk.

Aflatoxins express toxicity in humans and animals primarily by attacking the liver. The toxicity can occur from short-term consumption of very high doses of aflatoxin-contaminated grain or long-term ingestion of low levels of aflatoxins, possibly resulting in death for poultry, the most sensitive of the animal species. Livestock may experience reduced feed efficiency or reproduction, and both human and animal immune systems may be suppressed as a result of ingesting aflatoxins.

The FDA has established action levels for aflatoxin M1 in milk intended for human consumption and aflatoxins in human food, grain, and livestock feed (see table below).

The FDA has established additional policies and legal provisions concerning the blending of corn with levels of aflatoxins exceeding these threshold levels. In general, the FDA currently does not permit the blending of corn containing aflatoxin with uncontaminated corn to reduce the aflatoxin content of the resulting mixture to levels acceptable for use as human food or animal feed.

Corn exported from the United States must be tested for aflatoxins according to federal law. Unless the contract exempts this requirement, testing must be conducted by FGIS. Corn above the FDA action level of 20 ppb cannot be exported unless other strict conditions are met. This results in relatively low levels of aflatoxins in exported grain.

| Aflatoxins Action Level | Criteria |
|---|---|
| 0.5 ppb (Aflatoxin M1) | Milk intended for human consumption |
| 20 ppb | For corn and other grains intended for immature animals (including immature poultry) and for dairy animals, or when the animal's destination is not known |
| 20 ppb | For animal feeds, other than corn or cottonseed meal |
| 100 ppb | For corn and other grains intended for breeding beef cattle, breeding swine, or mature poultry |
| 200 ppb | For corn and other grains intended for finishing swine of 100 pounds or greater |
| 300 ppb | For corn and other grains intended for finishing (i.e., feedlot) beef cattle and for cottonseed meal intended for beef cattle, swine, or poultry |

*Source: FDA and USDA GIPSA, http://www.gipsa.usda.gov/Publications/fgis/broch/b-aflatox.pdf*

## Background: DON (Deoxynivalenol) or Vomitoxin

DON is another mycotoxin of concern to some importers of corn grain. It is produced by certain species of *Fusarium*, the most important of which is *Fusarium graminearum* (*Gibberellazeae*) which also causes Gibberella ear rot (or red ear rot). *Gibberellazeae* can develop when cool or moderate and wet weather occurs at flowering. The fungus grows down the silks into the ear, and in addition to producing DON, it produces conspicuous red discoloration of kernels on the ear. The fungus can also continue to grow and rot ears when corn is left standing in the field. Mycotoxin contamination of corn caused by *Gibberellazeae* is often associated with excessive postponement of harvest and/or storage of high-moisture corn.

DON is mostly a concern with monogastric animals, where it may cause irritation of the mouth and throat. As a result, the animals may eventually refuse to eat the DON-contaminated corn and may have low weight gain, diarrhea, lethargy, and intestinal hemorrhaging. It may cause suppression of the immune system resulting in susceptibility to a number of infectious diseases.

The FDA has issued advisory levels for DON. For products containing corn, the advisory levels are:

- 5 ppm in grains and grain co-products for swine, not to exceed 20% of their diet;
- 10 ppm in grains and grain co-products for chickens and cattle, not to exceed 50% of their diet; and
- 5 ppm in grains and grain co-products for all other animals, not to exceed 40% of their diet.

FGIS is not required to test for DON on corn bound for export markets, but will perform either a qualitative or quantitative test for DON at the buyer's request.

# A. 2016 HARVEST HIGHLIGHTS

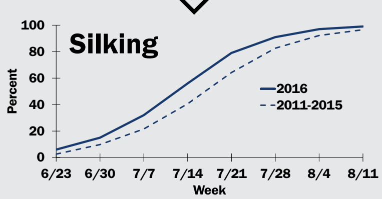
Weather plays a large role in the corn planting process, growing conditions, and grain development in the field, which, in turn, impacts final grain yield and quality. Overall, 2016 was characterized by a warm, dry vegetative period (the period of growth between germination and pollination), followed by a warm and wet grain-filling period and harvest. This crop was similar to 2014 with the best crop condition rating[1] during reproductive growth (the stages from silking through physiological maturity) in the past five years. The crop had excellent yields, greater test weight and oil concentration, and less stress cracks than the 2014 crop. The following highlights the key events of the 2016 growing season:

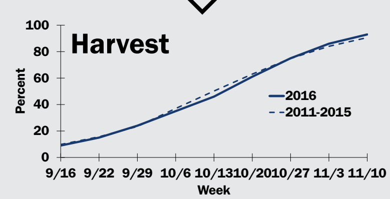
- Wide variation in temperatures and precipitation occurred in the spring.
- A warm spring overall, accompanied by the variable temperature and precipitation, led to prolonged emergence that, on average, was earlier than the 5 year average (5YA) emergence.
- Warm, dry weather during the vegetative stage encouraged rapid growth and healthy-looking plants.
- A wet reproductive period with warm nights created conditions that led to high potential for fungal diseases.
- Warm temperatures hastened maturity; rainy sites, especially in the Gulf ECA, delayed harvesting.
- Overall, the weather in 2016 led to high yields, with high test weight and oil averages.

The following sections describe how the 2016 growing season weather impacted corn yield and grain quality in the U.S. Corn Belt.

**GROWING CONDITIONS AND IMPACT ON CROP DEVELOPMENT**

| Variation in precipitation and temperature, accompanied by warm spring | Warm nighttime temperatures, 5th wettest summer on record | Normal-to-warm, but average-to-wet fall |
|---|---|---|


| Large variation in crop development at any given time | Good kernel volume and oil concentration, with some disease pressure | Average harvest progress, good weight and volume, and low levels of stress cracks |
|---|---|---|

*[1]The U.S. Department of Agriculture (USDA) rates the U.S. corn crop weekly during the production cycle. The rating is based on yield potential and plant stress due to a number of factors, including extreme temperatures, excessive or insufficient moisture, disease, insect damage, and/or weed pressure.*

# B. PLANTING AND EARLY GROWTH CONDITIONS

### *Warm, wet April led to wide variation in planting*

Weather factors impacting corn yield and quality include the amount of precipitation and the temperature just prior to and during the corn-growing season. These weather factors interact with the corn variety planted and the soil fertility. Grain yield is a function of the number of plants per acre, the number of kernels per plant, and the weight of each kernel. Cold or wet weather at planting could reduce plant numbers or hinder plant growth, which may result in lower yields per area. Some dryness at planting and early growth time is beneficial, as it promotes a deeper root system to access water better later in the season.

Overall in 2016, the spring was warmer than average for almost the entire United States. However, April was much wetter than normal, especially in the Pacific Northwest and Southern Rail ECAs, leading to an extended period of planting and emergence.

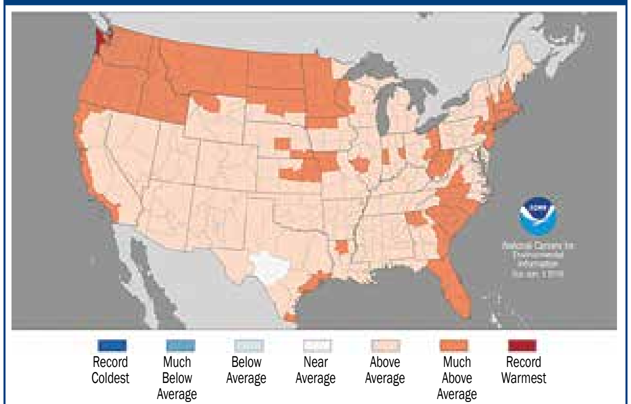
In the Pacific Northwest ECA, relatively warm temperatures in March led to average temperatures in April, and below-average temperatures in May. April was much wetter than normal, leading to many areas with delayed planting, or with early- and late-planted fields.

The majority of the Gulf ECA experienced average precipitation, but warmer-than-average temperatures during the spring months. Many areas west of the Mississippi River were much warmer and drier than average, which led to early planting, especially in Missouri.

The Southern Rail ECA was warm, but it experienced its fifth wettest spring (in over 122 years), which delayed corn planting, primarily in the north central to northeast part of the area.

**DIVISIONAL AVERAGE TEMPERATURE RANKS**
(Period: 1895-2016)

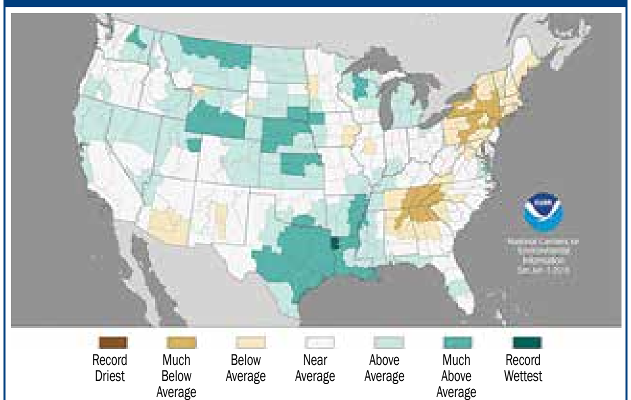
**MARCH-MAY 2016**




*Source: Regional Climate Centers*

**DIVISIONAL PRECIPITATION RANKS**
(Period: 1895-2016)

**MARCH-MAY 2016**




*Source: Regional Climate Centers*

## C. POLLINATION AND GRAIN-FILL CONDITIONS

### *Wet, warm summer favored high yields*

Corn pollination typically occurs in July, and at pollination time, greater-than-average temperatures or lack of rain typically reduce the number of kernels. The weather conditions during the grain-filling period in July and August are critical to determining final grain composition. During this time, moderate rainfall and cooler-than-average temperatures, especially overnight temperatures, promote starch and oil accumulation and increased yields. Moderate rainfall and warm temperatures in the second half of grain-fill (August to September) also aid continued nitrogen uptake and photosynthesis. Nitrogen also remobilizes from the leaves to the grain during late grain-filling, leading to increases in grain protein and hard endosperm.

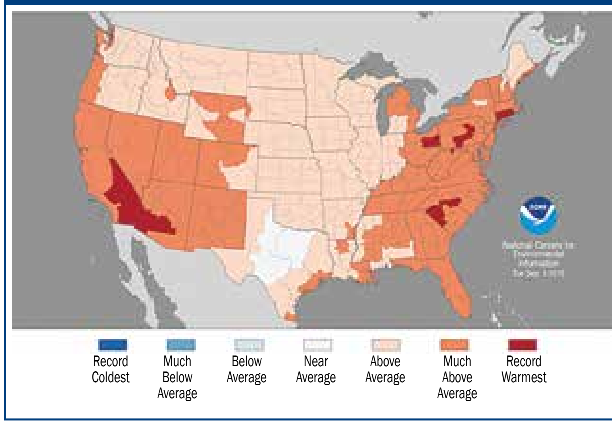
In 2016, areas in all of the ECAs changed from a very wet emergence period to a dry vegetative period, followed by abundant rains during the grain-filling period. In June, the warm weather and dry conditions favored rapid plant growth and nitrogen fertilizer uptake, producing a crop with a combined Good or Excellent condition rating that remained between 70-75% all season, conditions similar to the 2014 crop. The summer's above-average temperatures in the Gulf and Southern Rail ECAs were mostly associated with warmer nights, potentially causing starch-accumulation stress during grain-fill.

It is thought that dry weather before pollination, followed by wet weather the first three weeks after pollination, favors Diplodia fungal infection of corn ears, which causes lightweight kernels, cob rot damage, and potentially more broken corn and foreign material (BCFM). While 2016 had prime conditions for Diplodia throughout the United States, especially the Pacific Northwest and Gulf ECAs, corn varieties differ in their susceptibility, and Diplodia is not known to produce any toxin harmful to livestock.

**DIVISIONAL AVERAGE TEMPERATURE RANKS**

(Period: 1895-2016)

**JUNE-AUGUST 2016**




*Source: Regional Climate Centers*

In the Pacific Northwest ECA, June was very warm (top-10 warmest over 100 years), while July, with average temperatures, was followed by August experiencing cooler temperatures more in the western area. Overall, June was dry, with timely rains for pollination, and then patchy areas of both drought and localized heavy rainfall the remainder of the summer, potentially leading to greater-than-average variability in grain quality.

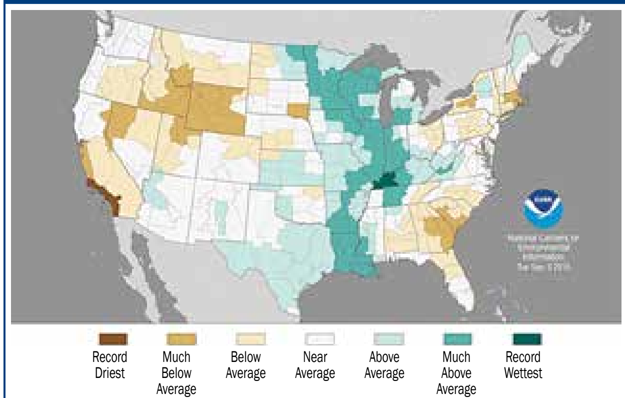
While the Gulf ECA experienced heavy rains, resulting in the fifth wettest summer on record, its rainfall was short of 2015's rainfall. Warm nights, due to high dew points, were common during grain-fill in the Gulf ECA, potentially limiting maximum starch concentration.

Overall, the Southern Rail ECA was abnormally dry in June (10th driest of the 1885-2016 period) and warm (10th warmest since 1896). The western area of the Southern Rail ECA experienced close-to-average temperatures, and the southern section had greater-than-average precipitation. During grain-fill, there were warm nighttime temperatures with abundant rains throughout the Southern Rail ECA. These weather conditions encouraged greater-than-average oil concentration.

**DIVISIONAL PRECIPITATION RANKS**

(Period: 1895-2016)

**JUNE-AUGUST 2016**




*Source: Regional Climate Centers*

# D. HARVEST CONDITIONS

## *Extended warm weather hastened maturation, but average harvest progress*

At the end of the growing season, the rate of dry down of the grain depends on sunshine, temperature, humidity levels, and soil moisture. Corn can most effectively dry down with the least adverse impact on quality amid sunny, warm, dry days. One weather concern at the end of the growing season is freezing temperatures. Early freezing before the grain can sufficiently dry down may lead to lower yield, test weight, and/or stress cracking. Also, if harvested prematurely, higher moisture grain may be susceptible to greater breakage than drier grain.

Typically, 80% of the U.S. corn crop is harvested by the end of October. Although this year's corn crop was ahead of schedule for maturity, rain hindered a timely harvest. Overall, despite abundant rains in September and October, harvest progressed close to the 5YA rate, with drier areas advancing more quickly to harvest. There was no widespread early freeze that would crack grain or lead to late-season disease and harvest issues.

*Fusarium*-based ear mold (Gibberella Ear Rot) is promoted by cool temperatures soon after pollination, which was generally not the case in 2016. The mycotoxin DON that is produced by *Fusarium* is often associated with harvest delay or storage of high-moisture corn. Several localized regions within the Gulf and some of the Pacific Northwest remained wet through harvest, resulting in a few areas of high-moisture corn. Overall, the 2016 season is experiencing an about-average harvest duration, and early-harvested grain will be dried to prevent further disease spread.

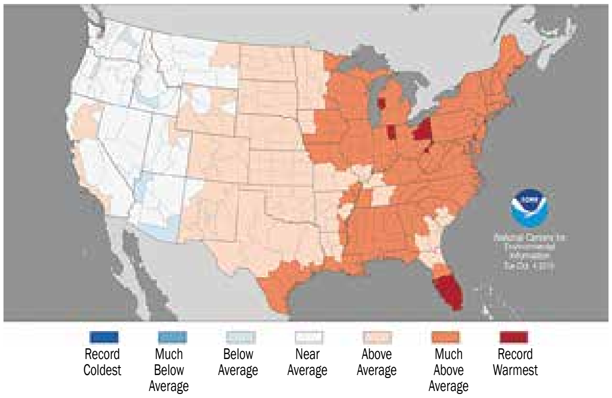
Additionally, aflatoxin production is favored by hot temperatures, low precipitation, and drought conditions. While it was warm in a large central portion of the corn-growing region, the plants had few extreme high-temperature days, and were not drought-stressed. Therefore, based on weather, aflatoxin should not be a problem this year.

U.S. GRAINS COUNCIL

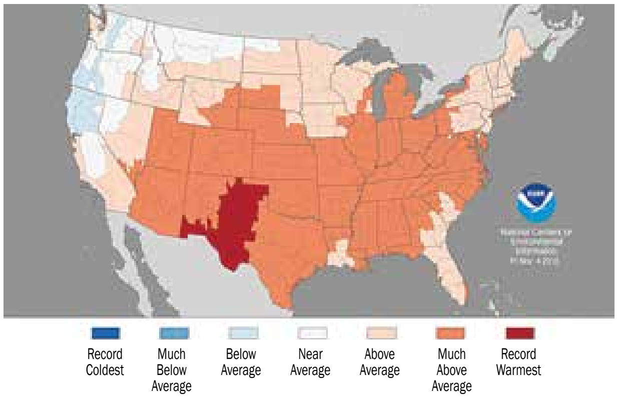
## DIVISIONAL AVERAGE TEMPERATURE RANKS

(Period: 1895-2016)

### SEPTEMBER 2016




### OCTOBER 2016

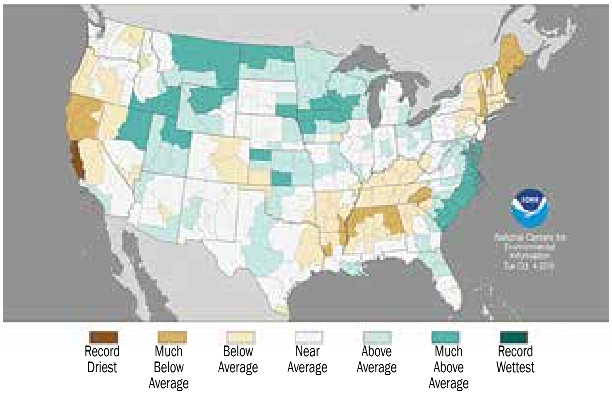



*Source: Regional Climate Centers*

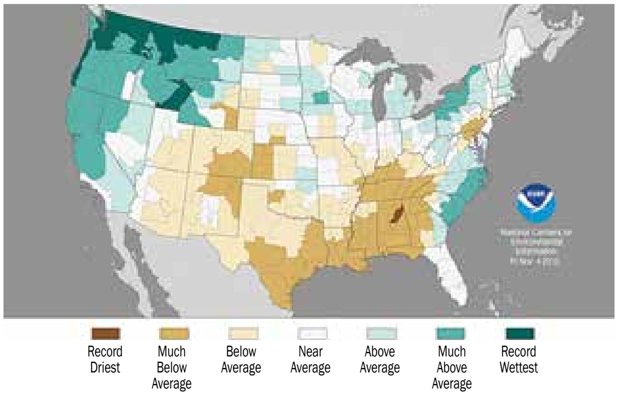
## DIVISIONAL PRECIPITATION RANKS

(Period: 1895-2016)

### SEPTEMBER 2016




### OCTOBER 2016

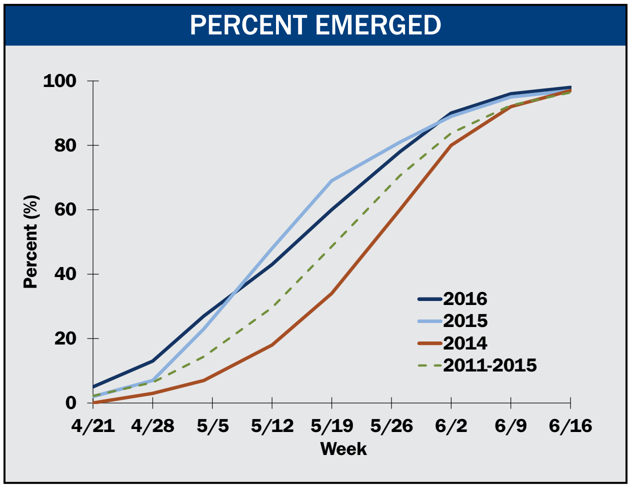



*Source: Regional Climate Centers*

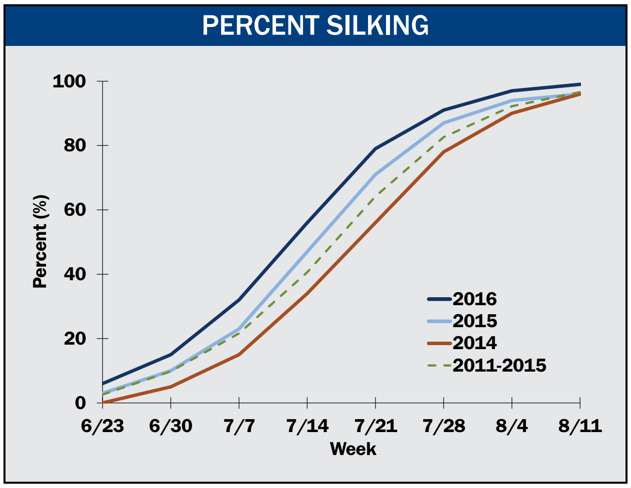
# E. COMPARISON OF 2016 TO 2015, 2014, AND 5YA

## *2016 was warmer and wetter at grain-fill than 2015, creating near-record yields*

While the 2014 crop year had near-normal emergence rates, in 2015, emergence was earlier than average. In contrast, overall emergence in 2016 progressed steadily across the time period. The rate at which the corn plants were silking in 2016 was similar to 2014 and 2015, and all the rates were slightly greater than the 5YA. In contrast to 2014 and 2015, when rains mostly tapered off to maximize pollination, in 2016, rains were plentiful during grain-fill, resulting in minimal drought areas.

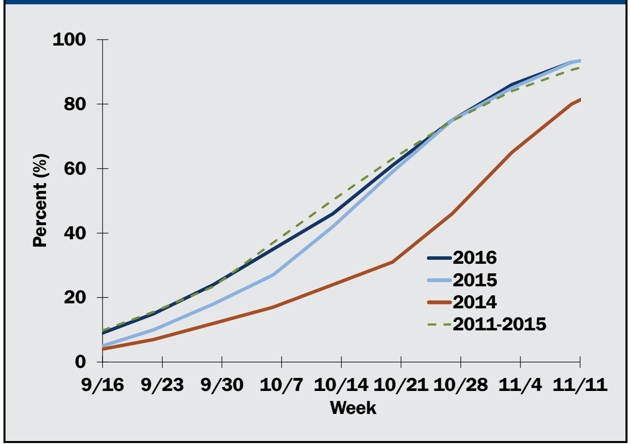



In contrast to the cool weather during the grain-fill period in 2014 and 2015, 2016 was very warm, inhibiting maximum starch accumulation. However, the heat during the 2016 period was not accompanied by drought, and was primarily caused by high night temperatures. Harvest progress in 2016 is similar to the 5YA. While harvest in 2015 had a slow start, it quickly surpassed the 5YA, in contrast to 2014, which was delayed by multiple weeks of rain and freezing temperatures.

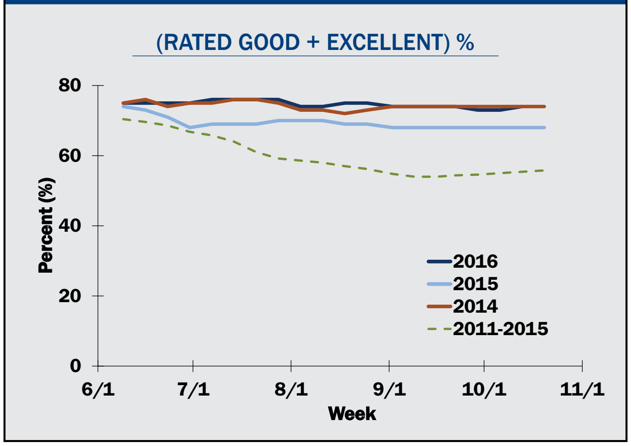


Throughout much of 2016, the corn crop had a near 75% Good or Excellent condition rating, signifying good plant health, leading to greater than average photosynthesis, kernel size, and yield[2]. This high rating was similar to 2014, which produced a record yield, and only slightly greater than 2015. In contrast, poorer growing conditions in 2011 through 2013 are reflected in the decreased 5YA, as shown on the graph. The corn crops in 2013 and 2011 were less healthy than 2014-2016, due to heat and drought. Additionally, in 2012, the severe drought and heat wave rapidly decreased the crop condition, starch accumulation, and yield, but increased grain test weight and protein concentration.

**PERCENT HARVESTED**




**U.S. CORN CONDITIONS**



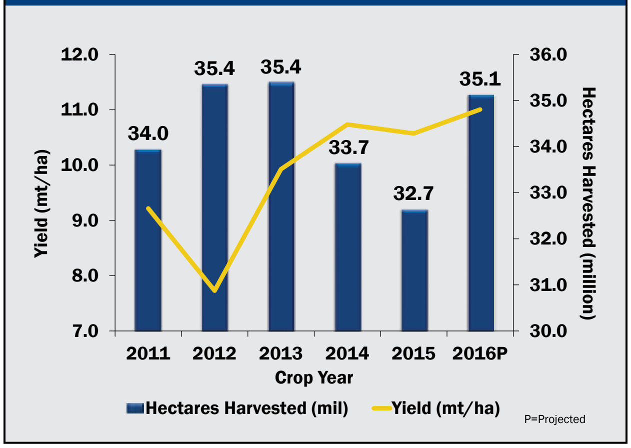

[2]*A 'Good' rating means that yield prospects are normal. Moisture levels are adequate and disease, insect damage, and weed pressures are minor. An 'Excellent' rating means that yield prospects are above normal, and the crop is experiencing little or no stress. Disease, insect damage, and weed pressures are insignificant.*

# A. U.S. CORN PRODUCTION[1]

## U.S. Average Production and Yields

- According to the November 2016 United States Department of Agriculture (USDA) World Agricultural Supply and Demand Estimates (WASDE) report, average U.S. corn yield for the 2016 crop is projected to be 11.0 mt/ha (175.3 bu/ac). This is 0.4 mt/ha (6.9 bu/ac) higher than the average yield for the 2015 corn crop and the highest average yield on record.
- The number of hectares harvested in 2016 is projected to be 35.1 million (86.8 mil ac). This is 2.4 mil ha (6.1 mil ac) more than in 2015. The projected 35.1 mil ha harvested in 2016 ranks third over the last 80 years and third-highest in the past 10 years.
- While 2016 saw the third-highest number of harvested hectares in the past decade, the 2016 crop also experienced the highest average yield on record, thereby producing a crop estimated to be the largest U.S. corn crop on record at 386.8 mmt (15,226 mil bu). This crop was about 41.3 mmt (1,625 mil bu) larger than 2015's crop (345.5 mmt or 13,601 mil bu).

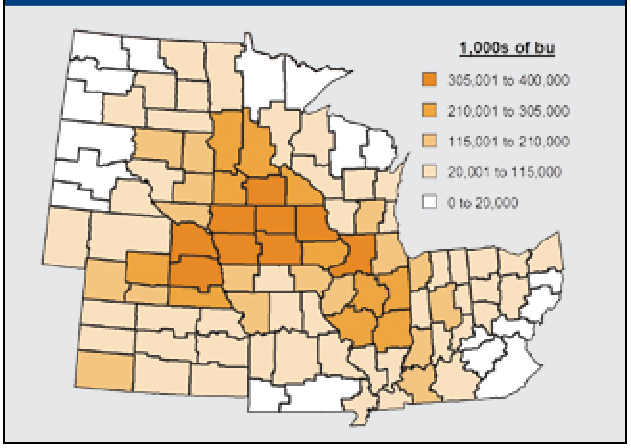
U.S. CORN YIELD AND HARVESTED AREA




## ASD and State-Level Production

The geographic areas included in the *2016/2017 Corn Harvest Quality Report* encompass the highest corn-producing areas in the United States. This can be seen on the map showing projected 2016 corn production by USDA Agricultural Statistical District (ASD).

U.S. CORN PRODUCTION BY ASD (2016P)

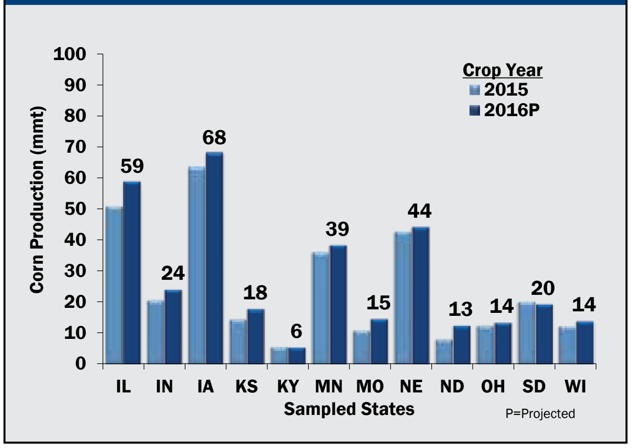



*Source: USDA NASS and Centrec Estimates*

[1] *mt - metric ton; mmt - million metric tons; ha - hectare; bu - bushel; mil bu - million bushels; ac - acre.*

Relative to the corn crop produced in 2015, the larger 2016 crop was driven by higher production in 10 of the 12 key corn-producing states. The largest increase in production levels occurred in Illinois, Iowa, Missouri, and North Dakota. Kentucky produced about the same amount of corn in 2016 as in 2015, while there was slightly lower production in South Dakota in 2016 than in 2015.

**U.S. CORN PRODUCTION BY STATE**




*Source: USDA NASS*

The U.S. Corn Production table summarizes the differences in both quantity (mmt) and percentages between 2015 and projected 2016 corn production for each state. Also included is an indication of the relative changes in harvested acres and yield between 2015 and projected 2016. The green bar indicates a relative increase and the red bar indicates a relative decrease from 2015 to projected 2016. This illustrates that harvested acres were largely unchanged to higher. Yield changes were mixed, with large increases (greater than 10%) in Illinois, Indiana, Missouri, and North Dakota, and slight decreases in only two states – Kentucky and South Dakota.

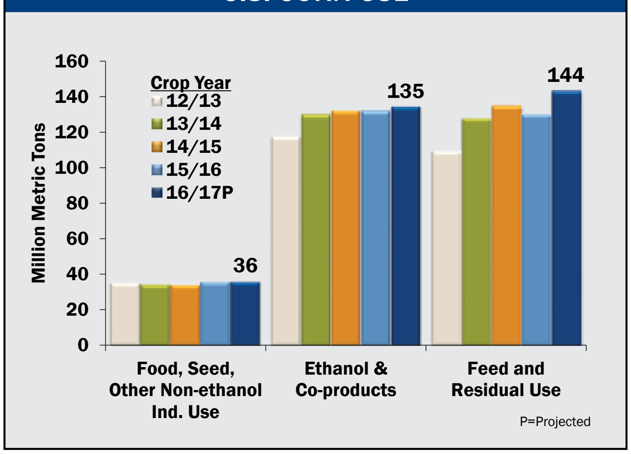
**U.S. CORN PRODUCTION**

| | | | Difference | | Relative % Change* | |
|---|---|---|---|---|---|---|
| State | 2015 | 2016P | MMT | Percent | Acres | Yield |
| Illinois | 51 | 59 | 8 | 15% | | |
| Indiana | 21 | 24 | 3 | 16% | | |
| Iowa | 64 | 68 | 5 | 7% | | |
| Kansas | 15 | 18 | 3 | 23% | | |
| Kentucky | 6 | 6 | (0) | -1% | | |
| Minnesota | 36 | 39 | 2 | 6% | | |
| Missouri | 11 | 15 | 4 | 34% | | |
| Nebraska | 43 | 44 | 1 | 3% | | |
| North Dakota | 8 | 13 | 4 | 53% | | |
| Ohio | 13 | 14 | 1 | 8% | | |
| South Dakota | 20 | 20 | (1) | -4% | | |
| Wisconsin | 12 | 14 | 2 | 13% | | |
| Total U.S. | 345 | 387 | 41 | 12% | | |

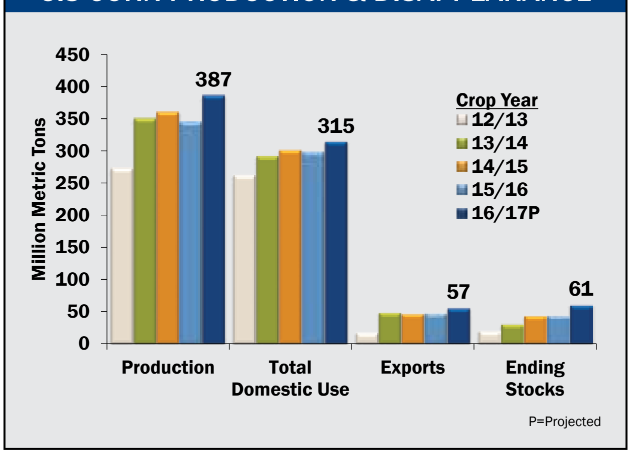
*Green indicates 2016 is higher than 2015 and red indicates 2016 is lower than 2015; bar height indicates the relative amount.*
*P=Projected, Source: USDA NASS*

# B. U.S. CORN USE AND ENDING STOCKS

- U.S. corn use for food, seed, and other non-ethanol industrial purposes has remained fairly constant over the past four completed marketing years, despite the lower production in the 2012/2013 marketing year (MY12/13) due to the drought.
- While the amount of corn used for ethanol production was lower in MY12/13 relative to MY13/14, MY14/15, and MY15/16, the amount of corn used for ethanol production has been stable in the past three completed marketing years.
- After rebounding from MY12/13 to MY13/14, direct consumption of corn as a feed ingredient in domestic livestock and poultry rations has remained strong, due to ample corn supplies and lower corn prices relative to other feed ingredients.
- U.S. corn exports have remained high since MY12/13, and have been influenced by multiple factors, including plentiful supply and strong export demand.
- The 2012 drought resulting in lower production greatly drew down the MY12/13 ending stocks, the lowest in many years. However, the large crops in MY13/14, MY14/15, and MY15/16 have helped rebuild ending stocks.




*Source: USDA WASDE and ERS*




*Source: USDA WASDE and ERS*

# C. OUTLOOK

## U.S. Outlook

- The record-setting size of the 2016 U.S. corn crop has created an abundant supply of corn for MY16/17. This ample supply has continued to keep downward pressure on corn prices since their peak in MY12/13. The ample supply and low prices are major factors driving the projected domestic use of corn in MY16/17 to be the highest on record.
- Corn use for food, seed, and non-ethanol industrial (FSI) purposes is expected to remain largely unchanged in MY16/17 compared to MY15/16, continuing the pattern of the previous four marketing years.
- Projected MY16/17 corn use for ethanol is slightly higher than the previous marketing year.

The rise in projected ethanol use is influenced, in part, by low gasoline prices supporting increased domestic gasoline demand, therefore expanding the domestic ethanol market. Other factors impacting the projected ethanol use include competitive ethanol blend prices, small increases in ethanol production efficiency, and moderate increases in substitution of corn as an ethanol feedstock.

- Domestic corn use for feed and residual use is expected to be 13.2 mmt higher (10.1% increase) in MY16/17 than in MY15/16. Feed demand for corn is expected to be supported by low corn prices, therefore decreasing the feed costs, and a large inventory of livestock and poultry.

- U.S. corn exports during MY16/17 are projected to be about 17% higher than last year and the highest since MY07/08. This projection is supported by an ample supply and a 6.6% increase in global demand from MY15/16 to MY16/17.

- MY16/17 corn ending stocks are projected to be 38.3% higher than the previous marketing year, primarily due to large corn crops in consecutive years. The stocks-to-use ratio is projected to be 16.4%, an increase for the fourth year in a row and a level not seen since MY05/06.

## International Outlook

### *Global Supply*

- Global corn production during MY16/17 is expected to be higher than MY14/15's record-setting production, due to larger crops in both the United States and other major corn-producing countries.

- Lower production for MY16/17 in China, Mexico, and Canada will be offset by greater production in Argentina, Brazil, the EU, South Africa, Southeast Asia, Ukraine, and the United States.

- In addition to higher projected U.S. exports, total non-U.S. exports are expected to be higher in MY16/17 than in MY15/16.

- Increased exports are also expected from the key non-U.S. exporting countries – Argentina, Brazil, and Ukraine.

### *Global Demand*

- Global corn use is expected to rise from 958.5 mmt in MY15/16 to 1,021.7 mmt in MY16/17, a 6.6% annual increase.

- With the exception of South Korea and Japan, corn use is anticipated to be higher in MY16/17 than in MY15/16 for the major importing countries and areas (Egypt, the EU, Mexico, and Southeast Asia). In addition, corn use is also projected to increase from MY15/16 to MY16/17 for the major exporting countries (Argentina, Brazil, Canada, South Africa, Ukraine, and the United States).

- A decrease in year-over-year imports is expected globally in MY16/17. An increase in imports by Turkey will be countered by decreases in projected MY16/17 corn imports in Egypt, Japan, Southeast Asia, and South Korea.

# U.S. CORN SUPPLY AND USAGE SUMMARY BY MARKETING YEAR

| Metric Units | 12/13 | 13/14 | 14/15 | 15/16 | 16/17P |
|---|---|---|---|---|---|
| **Acreage (million hectares)** | | | | | |
| Planted | 39.4 | 38.6 | 36.7 | 35.6 | 38.3 |
| Harvested | 35.4 | 35.4 | 33.7 | 32.7 | 35.1 |
| Yield (mt/ha) | 7.7 | 9.9 | 10.7 | 10.6 | 11.0 |
| **Supply (million metric tons)** | | | | | |
| Beginning stocks | 25.1 | 20.9 | 31.3 | 44.0 | 44.1 |
| Production | 273.2 | 351.3 | 361.1 | 345.5 | 386.8 |
| Imports | 4.1 | 0.9 | 0.8 | 1.7 | 1.3 |
| **Total Supply** | **302.4** | **373.0** | **393.2** | **391.2** | **432.2** |
| | | | | | |
| **Usage (million metric tons)** | | | | | |
| Food, seed, other non-ethanol ind. use | 35.5 | 34.8 | 34.5 | 36.3 | 36.5 |
| Ethanol and co-products | 117.9 | 130.1 | 132.3 | 132.2 | 134.6 |
| Feed and residual | 109.6 | 128.0 | 135.0 | 130.3 | 143.5 |
| Exports | 18.5 | 48.8 | 47.4 | 48.2 | 56.5 |
| **Total Use** | **281.5** | **341.8** | **349.3** | **347.1** | **371.1** |
| Ending Stocks | 20.9 | 31.3 | 44.0 | 44.1 | 61.0 |
| Average Farm Price ($/mt*) | 271.25 | 175.58 | 145.662 | 142.118 | 118.104-141.725 |

| English Units | 12/13 | 13/14 | 14/15 | 15/16 | 16/17P |
|---|---|---|---|---|---|
| **Acreage (million acres)** | | | | | |
| Planted | 97.3 | 95.4 | 90.6 | 88.0 | 94.5 |
| Harvested | 87.4 | 87.5 | 83.1 | 80.7 | 86.8 |
| Yield (bu/ac) | 123.1 | 158.1 | 171.0 | 168.4 | 175.3 |
| **Supply (million bushels)** | | | | | |
| Beginning stocks | 989 | 821 | 1,232 | 1,731 | 1,738 |
| Production | 10,755 | 13,829 | 14,216 | 13,601 | 15,226 |
| Imports | 160 | 36 | 32 | 67 | 50 |
| **Total Supply** | **11,904** | **14,686** | **15,479** | **15,399** | **17,014** |
| | | | | | |
| **Usage (million bushels)** | | | | | |
| Food, seed, other non-ethanol ind. use | 1,397 | 1,370 | 1,359 | 1,429 | 1,435 |
| Ethanol and co-products | 4,641 | 5,124 | 5,209 | 5,206 | 5,300 |
| Feed and residual | 4,315 | 5,040 | 5,315 | 5,130 | 5,650 |
| Exports | 730 | 1,920 | 1,867 | 1,898 | 2,225 |
| **Total Use** | **11,083** | **13,454** | **13,750** | **13,663** | **14,610** |
| Ending Stocks | 821 | 1,232 | 1,731 | 1,738 | 2,403 |
| Average Farm Price ($/bu*) | 6.89 | 4.46 | 3.70 | 3.61 | 3.00-3.60 |

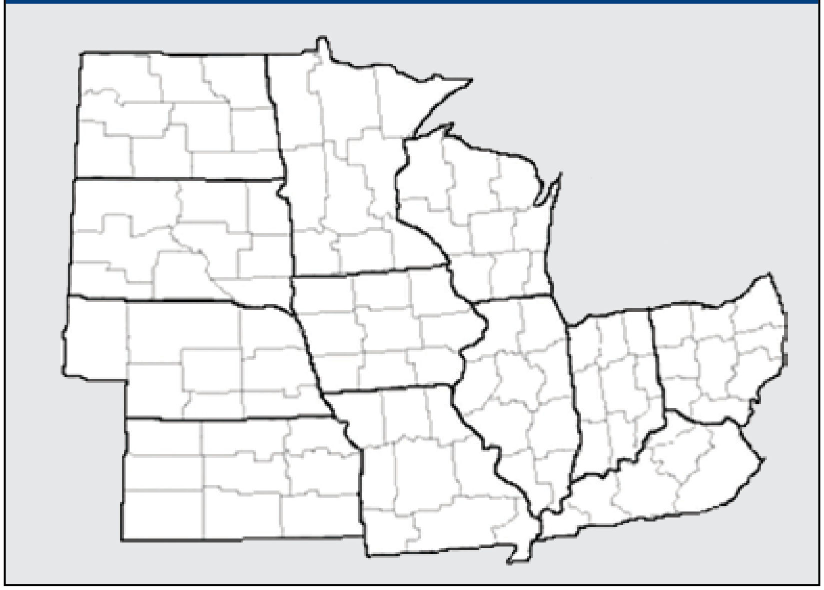
*P-Projected*
**Farm prices are weighted averages based on volume of farm shipment.*
*Average farm price for 16/17P based on WASDE November projected price.*
*Source: USDA WASDE and ERS*

# A. OVERVIEW

The key points for the survey design and sampling and statistical analysis for this *2016/2017 Harvest Report* are as follows:

- Following the methodology developed for the previous five *Harvest Reports*, the samples were proportionately stratified according to Agricultural Statistical Districts (ASDs) across 12 key corn-producing states representing 93.1% of U.S. corn exports.
- A total of 617 samples collected from the 12 states were targeted to achieve a maximum ±10% relative margin of error (Relative ME) at the 95% confidence level.
- A total of 624 unblended corn samples pulled from inbound farm-originated trucks were received from local elevators from September 8 through November 28, 2016, and tested.
- A proportionate stratified sampling technique was used for the mycotoxin testing across the ASDs in the 12 states surveyed for the other quality factors. This sampling resulted in 177 samples being tested for aflatoxins and DON.
- Weighted averages and standard deviations following standard statistical techniques for proportionate stratified sampling were calculated for the U.S. Aggregate and the three Export Catchment Areas (ECAs).
- To evaluate the statistical validity of the samples, the Relative ME was calculated for each of the quality attributes at the U.S. Aggregate and the three ECA levels. The Relative ME for the quality factor results was less than ±10% except for two attributes – stress cracks and stress crack index (SCI). While the lower level of precision for these quality factors is less than desired, these levels of Relative ME do not invalidate the estimates.
- Two-tailed t-tests at the 95% confidence level were calculated to measure statistical differences between the 2016 and 2015 and the 2016 and 2014 quality factor averages.

**AGRICULTURAL STATISTICAL DISTRICTS (ASDs)**



# B. SURVEY DESIGN AND SAMPLING

## Survey Design

For this *2016/2017 Harvest Report*, the target population was yellow commodity corn from the 12 key U.S. corn-producing states representing about 93.1% of U.S. corn exports. A ***proportionate stratified, random sampling*** technique was applied to ensure a sound statistical sampling of the U.S. corn crop at the first stage of the market channel. Three key characteristics define the sampling technique: the ***stratification*** of the population to be sampled, the ***sampling proportion*** per stratum, and the ***random sample*** selection procedure.

***Stratification*** involves dividing the survey population of interest into distinct, non-overlapping subpopulations called strata. For this study, the survey population was corn produced in areas likely to export corn to foreign markets. The U.S. Department of Agriculture (USDA) divides each state into several Agricultural Statistical Districts (ASDs) and estimates corn production for each ASD. The USDA corn production data, accompanied by foreign export estimates, were used to define the survey population in 12 key corn-producing states representing 93.1% of U.S. corn exports (Source: USDA/GIPSA). The ASDs were the subpopulations or strata used for this corn quality survey. From those data, the Council calculated each ASD's proportion of the total production and foreign exports to determine the ***sampling proportion*** (the percent of total samples per ASD) and ultimately, the number of corn samples to be collected from each ASD. The number of samples collected for the *2016/2017 Harvest Report* differed among the ASDs, due to their different shares of estimated production and foreign export levels.

The ***number of samples collected was established*** so the Council could estimate the true averages of the various quality factors with a certain level of precision. The level of precision chosen for the *2016/2017 Harvest Report* was a relative margin of error (Relative ME) no greater than ±10%, estimated at a 95% level of confidence. A Relative ME of ±10% is a reasonable target for biological data such as these corn quality factors.

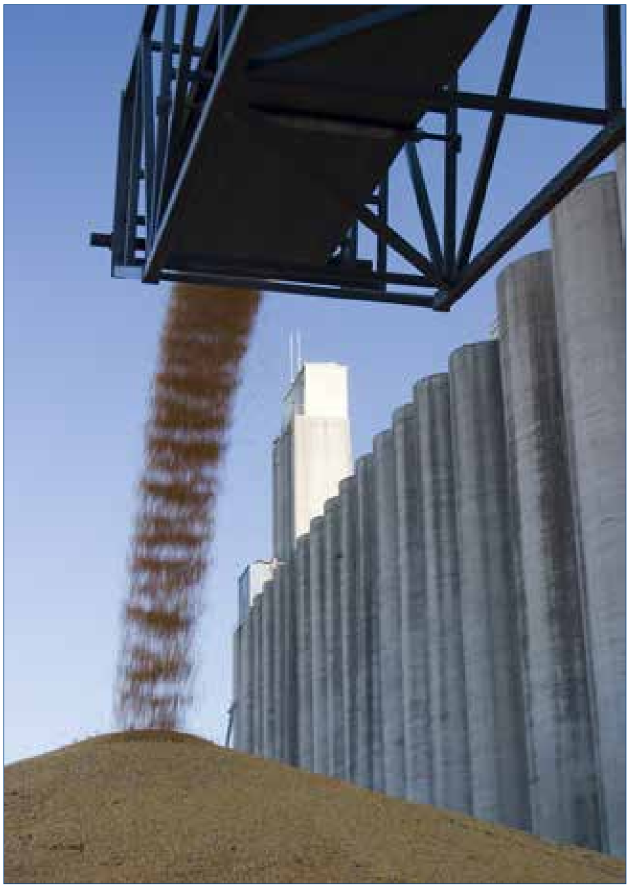
To determine the number of samples for the targeted Relative ME, ideally the population variance (i.e., the variability of the quality factor in the corn at harvest) for each of the quality factors should be used. The more variation among the levels or values of a quality factor, the more samples needed to estimate the true mean with a given confidence limit. In addition, the variances of the quality factors typically differ from one another. As a result, different sample sizes for each of the quality factors would be needed for the same level of precision.

Since the population variances for the 17 quality factors evaluated for this year's corn crop were not known, the variance estimates from the *2015/2016 Harvest Report* were used as proxies. The variances and ultimately the estimated number of samples needed for the Relative ME of ±10% for 14 quality factors were calculated using the 2015 results of 620 samples. Broken corn, foreign material, and heat damage were not examined. Stress cracks and stress crack index (SCI), with a Relative ME of 11% and 14%, respectively, were the only quality factors for which the Relative ME exceeded ±10% for the U.S. Aggregate. Based on these data, a minimum sample size of 600 would allow the Council to estimate the true averages of the quality characteristics with the desired level of precision for the U.S. Aggregate, with the exception of stress cracks and SCI. However, the targeted number of samples became 617, due to the rounding of targeted numbers of samples per ASD, and the criterion of a minimum of two samples per ASD.

The same approach of proportionate stratified sampling was used for the mycotoxin testing of the corn samples as for the testing of the grade, moisture, chemical, and physical characteristics. In addition to using the same sampling approach, the same level of precision of a Relative ME of ±10%, estimated at a 95% level of confidence, was desired. Testing at least 25% of the minimum number of samples (600) was estimated to provide that level of precision. In other words, testing at least 150 samples would provide a 95% confidence level that the percent of tested samples with aflatoxin results below the FDA action level of 20 parts per billion (ppb) would have a Relative ME of ±10%. In addition, it was estimated that the percent of tested samples with DON results below the FDA advisory level of 5 parts per million (ppm) would also have a Relative ME of ±10%, estimated at a 95% level of confidence. The proportionate stratified sampling approach also required testing at least one sample from each ASD in the sampling area. To meet the sampling criteria of testing 25% of the minimum number of samples (600) and at least one sample from each ASD, the targeted number of samples to test for mycotoxins was 177 samples.

## Sampling

The ***random selection*** process was implemented by soliciting local grain elevators in the 12 states by mail, email, and phone. Postage-paid sample kits were mailed to elevators agreeing to provide the 2050- to 2250-gram corn samples requested. Samples were collected from the elevators when at least 30% of the corn in their area had been harvested. The 30% harvest threshold was established to avoid receiving old crop corn samples as farmers cleaned out their bins for the current crop or new crop harvested earlier than normal for reasons such as elevator premium incentives. The individual samples were pulled from inbound farm-originated trucks when the trucks underwent the elevators' normal testing procedures. The number of samples each elevator provided for the survey depended on the targeted number of samples needed from the ASD along with the number of elevators willing to provide samples. A maximum of four samples from each physical location was collected. A total of 624 unblended corn samples pulled from inbound farm-originated trucks was received from local elevators from September 8 through November 28, 2016, and tested.

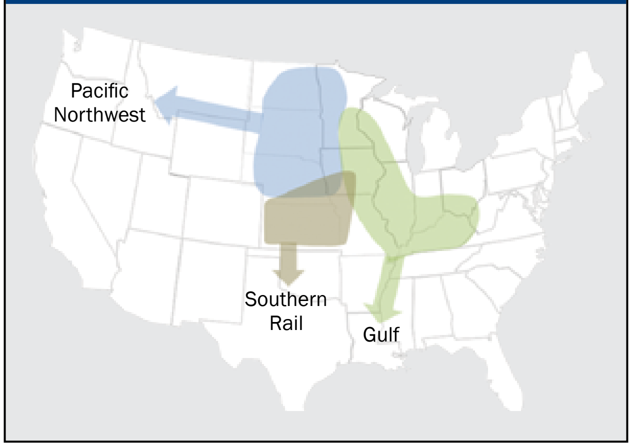


# C. STATISTICAL ANALYSIS

The sample test results for the grade factors, moisture, chemical composition, and physical factors were summarized as the U.S. Aggregate and also by three composite groups that supply corn to each of three major export channels, labeled Export Catchment Areas (ECAs), as follows:

- The Gulf ECA consists of areas that typically export corn through the U.S. Gulf ports;
- The Pacific Northwest (PNW) ECA includes areas that export corn through Pacific Northwest and California ports; and
- The Southern Rail ECA comprises areas generally exporting corn to Mexico by rail from inland subterminals.

**EXPORT CATCHMENT AREAS**




In analyzing the sample test results, the Council followed the standard statistical techniques employed for proportionate stratified sampling, including ***weighted averages*** and ***standard deviations***. In addition to the weighted averages and standard deviations for the U.S. Aggregate, weighted averages and standard deviations were estimated for the composite ECAs. The geographic areas from which exports flow to each of these ECAs overlap due to available transportation modes. Therefore, composite statistics for each ECA were calculated based on estimated proportions of grain flowing to each ECA. As a result, corn samples could be reported in more than one ECA. These estimations were based on industry input, export data, and evaluation of studies of grain flow in the United States.

New to this *2016/2017 Harvest Report* is a simple average of the quality factors' averages and standard deviations of the previous five *Harvest Reports (2011/2012, 2012/2013, 2013/2014, 2014/2015,* and *2015/2016)*. These simple averages are calculated for the U.S. Aggregate and each of the three ECAs and are referred to as "5YA" in the text and summary tables of the report.

The Relative ME was calculated for each of the quality factors for the U.S. Aggregate and each of the ECAs. The Relative ME was less than ±10% for all the quality attributes, except for stress cracks and SCI, for the U.S. Aggregate and the Gulf, Pacific Northwest, and Southern Rail ECAs. The Relative ME for stress cracks and SCI are shown in the table below.

| | Relative ME | |
|---|---|---|
| | Stress Cracks | SCI |
| U.S. Aggregate | 12% | 15% |
| Gulf ECA | 13% | 16% |
| Pacific Northwest ECA | 17% | 19% |
| Southern Rail ECA | 15% | 19% |

While the lower level of precision for these quality factors is less than desired, these levels of Relative ME do not invalidate the estimates. Footnotes in the summary tables for "Grade Factors and Moisture" and "Physical Factors" indicate the attributes for which the Relative ME exceeds ±10%.

References in the "Quality Test Results" section to statistical and/or significant differences between results in the *2015/2016 Harvest Report* and the *2016/2017 Harvest Report*, and in the *2014/2015 Harvest Report* and the *2016/2017 Harvest Report*, were validated by two-tailed t-tests at the 95% confidence level.

The *2016/2017 Corn Harvest Quality Report* samples (each about 2200 grams) were sent directly from the local grain elevators to the Illinois Crop Improvement Association's Identity Preserved Grain Laboratory (IPG Lab) in Champaign, Illinois. Upon arrival, the samples were dried, if needed, to a suitable moisture content to prevent any subsequent deterioration during the testing period. Next, the samples were split into two 1100-gram subsamples using a Boerner divider, while keeping the attributes of the grain sample evenly distributed between the two subsamples. One subsample was delivered to the Champaign-Danville Grain Inspection (CDGI) for grading. CDGI is the official grain inspection service provider for east-central Illinois as designated by USDA's Federal Grain Inspection Service (FGIS). The grade testing procedures were in accordance with FGIS's *Grain Inspection Handbook* and are described in the following section. The other subsample was analyzed at IPG Lab for the chemical composition and other physical factors, following either industry norms or well-established procedures in practice for many years. IPG Lab has received accreditation under the ISO/IEC 17025:2005 International Standard for many of the tests. The full scope of accreditation is available at *http://www.ilcrop.com/perry-johnson-laboratory-accreditation*.

# A. CORN GRADING FACTORS

## Test Weight

Test weight is a measure of the volume of grain that is required to fill a Winchester bushel (2,150.42 cubic inches) to capacity. Test weight is a part of the FGIS Official U.S. Standards for Corn 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 traditional U.S. unit, pounds per bushel (lb/bu).

## Broken Corn and Foreign Material (BCFM)

Broken corn and foreign material (BCFM) is part of the FGIS Official U.S. Standards for Grain and grading criteria.

The BCFM test determines the amount of all matter that passes through a $12/64^{th}$-inch round-hole sieve and all matter other than corn that remains on the top of the sieve. BCFM measurement can be separated into broken corn and foreign material. Broken corn is defined as all material passing through a $12/64^{th}$-inch round-hole sieve and retained on a $6/64^{th}$-inch round-hole sieve. Foreign material is defined as all material passing through the $6/64^{th}$-inch round-hole sieve and the coarse non-corn material retained on top of the $12/64^{th}$-inch round-hole sieve. BCFM is reported as a percentage of the initial sample by weight.

## Total Damage/Heat Damage

Total damage is part of the FGIS Official U.S. Standards for Grain grading criteria.

A representative working sample of 250 grams of BCFM-free corn is visually examined by a trained and licensed inspector for content of damaged kernels. Types of damage include blue-eye mold, cob rot, dryer-damaged kernels (different from heat-damaged kernels), germ-damaged kernels, heat-damaged kernels, insect-bored kernels, mold-damaged kernels, mold-like substance, silk-cut kernels, surface mold (blight), mold (pink *Epicoccum*), and sprout-damaged kernels. Total damage is reported as the weight percentage of the working sample that is total damaged grain.

Heat damage is a subset of total damage and consists of kernels and pieces of corn kernels that are materially discolored and damaged by heat. Heat-damaged kernels are determined by a trained and licensed inspector visually inspecting a 250-gram sample of BCFM-free corn. Heat damage, if found, is reported separately from total damage.

# B. MOISTURE

The moisture recorded by the elevators' electronic moisture meters at the time of delivery is reported. Electronic moisture meters sense an electrical property of grains called the dielectric constant that varies with moisture. The dielectric constant rises as moisture content increases. Moisture is reported as a percent of total wet weight.

# C. CHEMICAL COMPOSITION

## NIR Proximate Analysis

The chemical composition (protein, oil, and starch concentration) of corn is measured using Near-infrared transmission spectroscopy (NIR). The NIR uses unique interactions of specific wavelengths of light with each sample. It is calibrated to traditional chemistry methods, to predict the concentrations of oil, protein, and starch in the sample. This procedure is nondestructive to the corn.

Chemical composition tests for protein, oil, and starch in fall 2016 were conducted using a 550- to 600-gram sample in a whole-kernel Foss Infratec 1241 Near-Infrared Transmittance (NIR) instrument. The NIR was calibrated to chemical tests, and the standard error of predictions for protein, oil, and starch were about 0.27%, 0.25%, and 0.66%, respectively. Comparisons of the Foss Infratec 1229 used in previous *Harvest Reports* to the new Foss Infratec 1241 in fall 2016 on 21 laboratory check samples showed the instruments averaged within 0.25, 0.26, and 0.25% points of each other for protein, oil, and starch, respectively.  Results are reported on a dry basis percentage (percent of non-water material).

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# D. PHYSICAL FACTORS

## 100-Kernel Weight, Kernel Volume, and Kernel True Density

The 100-kernel weight is determined from the average weight of two 100-kernel replicates using an analytical balance that measures to the nearest 0.1 mg. The averaged 100-kernel weight is reported in grams.

The kernel volume for each 100-kernel replicate is calculated using a helium pycnometer and is expressed in cubic centimeters ($cm^3$) per kernel. Kernel volumes usually range from 0.18-0.30 $cm^3$ per kernel for small and large kernels, respectively.

True density of each 100-kernel sample is calculated by dividing the mass (or weight) of the 100 externally sound kernels by the volume (displacement) of the same 100 kernels. The two replicate results are averaged. True density is reported in grams per cubic centimeter ($g/cm^3$). True densities typically range from 1.16 to 1.35 $g/cm^3$ at "as is" moistures of about 12 to 15%.

## Stress Crack Analysis

Stress cracks are evaluated by using a backlit viewing board to accentuate the cracks. A sample of 100 intact kernels with no external damage is examined kernel by kernel. The light passes through the horneous or hard endosperm so the severity of the stress crack damage in each kernel can be evaluated. Kernels are sorted into four categories: (1) no cracks; (2) one crack; (3) two cracks; and (4) more than two cracks. Stress cracks, expressed as a percent, are all kernels containing one, two, or more than two cracks divided by 100 kernels. Lower levels of stress cracks are always better since higher levels of stress cracks lead to more breakage in handling. If stress cracks are present, singles are better than doubles or multiples. Some corn end users will specify the acceptable level of cracks based on the intended use.

Stress crack index (SCI) is a weighted average of the stress cracks. This measurement indicates the severity of stress cracking. SCI is calculated as:

SCI = [SSC x 1] + [DSC x 3] + [MSC x 5]

Where

- SSC is the percentage of kernels with only one crack;
- DSC is the percentage of kernels with exactly two cracks; and
- MSC is the percentage of kernels with more than two cracks.

The SCI can range from 0 to 500, with a high number indicating numerous multiple stress cracks in a sample, which is undesirable for most uses.

## Whole Kernels

In the whole kernels test, 50 grams of cleaned (BCFM-free) corn are inspected kernel by kernel. Cracked, broken, or chipped grain, along with any kernels showing significant pericarp damage, are removed. The whole kernels are then 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%.

## Horneous (Hard) Endosperm

The horneous (or hard) endosperm test is performed by visually rating 20 externally sound kernels, placed germ facing up, on a backlit viewing board. Each kernel is rated for the estimated portion of the kernel's total endosperm that is horneous endosperm. Soft endosperm is opaque and will block light, while horneous endosperm is translucent. The 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. The average of horneous endosperm ratings for the 20 externally sound kernels is reported. Ratings of horneous endosperm are made on a scale of 70 to 100%, though most individual kernels fall in the 70 to 95% range.

## Mycotoxin Testing

Detection of mycotoxins in corn is complex. The fungi producing the mycotoxins often do not grow uniformly in a field or across a geographic area. As a result, the detection of any mycotoxin in corn, if present, is highly dependent upon the concentration and distribution of the mycotoxin among kernels in a lot of corn, whether a truck load, a storage bin, or a railcar.

The objective of the FGIS sampling process is to minimize underestimating or overestimating the true mycotoxin concentration, since accurate results are imperative for corn exports. However, the objective of the *2016/2017 Corn Harvest Quality Report* assessment of mycotoxins is only to report the frequency of occurrences of the mycotoxin in the current crop, and not to report specific levels of the mycotoxin in corn exports.

To report the frequency of occurrences of aflatoxins and DON for the *2016/2017 Corn Harvest Quality Report*, IPG Lab performed the mycotoxin testing using FGIS protocol and approved test kits. FGIS's protocol requires a minimum of a 908-gram (2-pound) sample from trucks to grind for aflatoxin testing and approximately a 200-gram sample to grind for DON testing. For this study, a 1000-gram laboratory sample was subdivided from the 2-kg survey sample of shelled kernels for the aflatoxin analysis. The 1-kg survey sample was ground in a Romer Model 2A mill so that 60-75% would pass a 20-mesh screen. From this well-mixed ground material, a 50-gram test portion was removed for each mycotoxin tested. EnviroLogix AQ 109 BG and AQ 254 BG quantitative test kits were used for the aflatoxin and DON analysis, respectively. The DON was extracted with water (5:1), while the aflatoxins were extracted with 50% ethanol (2:1). The extracts were tested using the Envirologix QuickTox lateral flow strips, and the mycotoxins were quantified by the QuickScan system.

The EnviroLogix quantitative test kits report specific concentration levels of the mycotoxin if the concentration level exceeds a specific level called a "Limit of Detection" (LOD). The LOD is defined as the lowest concentration level that can be measured with an analytical method that is statistically different from measuring an analytical blank (absence of a mycotoxin). The LOD will vary among different types of mycotoxins, test kits, and commodity combinations. The LOD for the EnviroLogix AQ 109 BG and AQ 254 BG are 2.5 parts per billion (ppb) for aflatoxins and 0.3 parts per million (ppm) for DON.

A letter of performance has been issued by FGIS for the quantification of aflatoxins and DON using the Envirologix AQ 109 BG and AQ 254 BG kits, respectively.

## U.S. CORN GRADES AND GRADE REQUIREMENTS

| | | Maximum Limits of | | |
|---|---|---|---|---|
| | | Damaged Kernels | | |
| Grade | Minimum Test Weight per Bushel (Pounds) | Heat Damaged (Percent) | Total (Percent) | Broken Corn and Foreign Material (Percent) |
| U.S. No. 1 | 56.0 | 0.1 | 3.0 | 2.0 |
| U.S. No. 2 | 54.0 | 0.2 | 5.0 | 3.0 |
| U.S. No. 3 | 52.0 | 0.5 | 7.0 | 4.0 |
| U.S. No. 4 | 49.0 | 1.0 | 10.0 | 5.0 |
| U.S. No. 5 | 46.0 | 3.0 | 15.0 | 7.0 |

U.S. Sample Grade is corn that: (a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or (b) Contains stones with an aggregate weight in excess of 0.1 percent of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria spp.*), 2 or more castor beans (*Ricinus communis L.*), 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cockleburs (*Xanthium spp.*), or similar seeds singly or in combination, or animal filth in excess of 0.20 percent in 1,000 grams; or (c) Has a musty, sour, or commercially objectionable foreign odor; or (d) Is heating or otherwise of distinctly low quality.

Source: Code of Federal Regulations, Title 7, Part 810, Subpart D, United States Standards for Corn

## U.S. AND METRIC CONVERSIONS

| Corn Equivalents | | Metric Equivalents | |
|---|---|---|---|
| 1 bushel = | 56 pounds (25.40 kilograms) | 1 pound = | 0.4536 kg |
| 39.368 bushels = | 1 metric ton | 1 hundredweight = | 100 pounds or 45.36 kg |
| 15.93 bushels/acre = | 1 metric ton/hectare | 1 metric ton = | 2204.6 lbs |
| 1 bushel/acre = | 62.77 kilograms/hectare | 1 metric ton = | 1000 kg |
| 1 bushel/acre = | 0.6277 quintals/hectare | 1 metric ton = | 10 quintals |
| 56 lbs/bushel = | 72.08 kg/hectoliter | 1 quintal = | 100 kg |
| | | 1 hectare = | 2.47 acres |

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