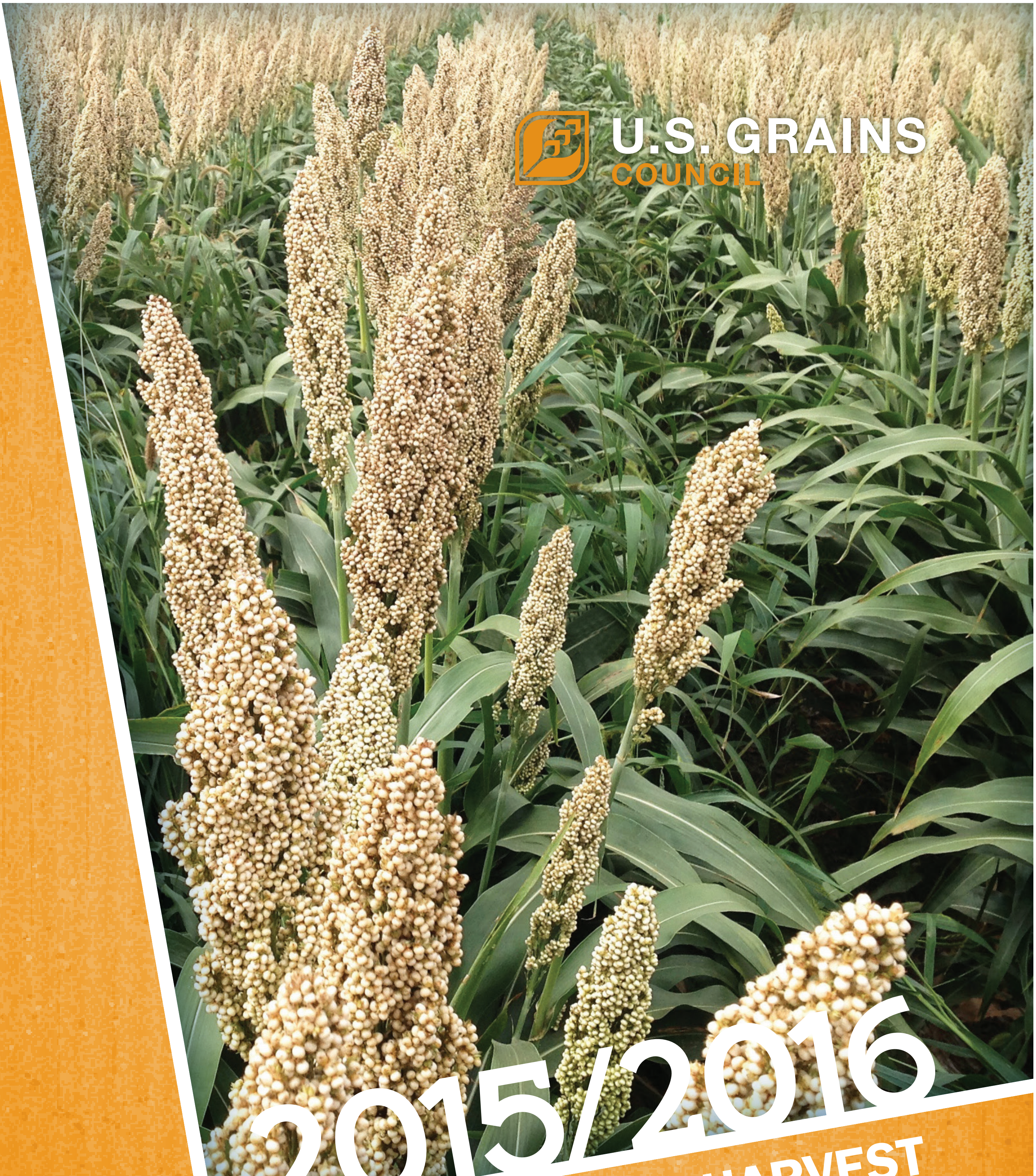

U.S. GRAINS COUNCIL

2015/2016

SORGHUM EARLY HARVEST QUALITY REPORT

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) and the United Sorghum Checkoff Program (Sorghum Checkoff) are 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. Curt Weller, Joseph Awika, Tom Whitaker, and Marvin R. Paulsen. In addition, the Council is indebted to the Cereal Quality Lab (CQL) at Texas A&M and Amarillo Grain Exchange (AGE), which provided the sorghum 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.

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GREETINGS FROM THE COUNCIL

We are pleased to provide U.S. sorghum customers and U.S. Grains Council members with the *U.S. Grains Council's 2015/2016 Sorghum Early Harvest Quality Report*, the first in a new annual series.

Accurate and timely information on crop quality helps buyers make more informed decisions and increases their confidence in the capacity and reliability of the market. The main objective of this early harvest report is to offer a transparent view of the United States' most recent sorghum crop's quality as the earliest harvested sorghum comes out of the field.

Sorghum quality characteristics that are observed by buyers will be further affected by subsequent handling, blending and storage. A second report, the *U.S. Grains Council's 2015/2016 Sorghum Harvest and Export Cargo Quality Report*, will measure sorghum quality from production areas sampled later in the 2015 harvest season and at export terminals at the point of loading for international shipment.

The Council is committed to global food security and mutual economic benefit through trade. As a bridge between international sorghum buyers and one of the world's largest and most sophisticated agricultural export systems, the Council offers this report as a service to our partners around the world in support of our mission of *Developing Markets, Enabling Trade and Improving Lives*.

Sincerely,

Alan Tiemann

Alan Tiemann
Chairman, U.S. Grains Council
November 2015

I. HARVEST QUALITY HIGHLIGHTS

The 2015 U.S. sorghum crop is expected to be the largest since 1999, thanks to projected high yields and acreage. Setting the stage for the entire 2015 U.S. sorghum crop, the Early Harvest sorghum crop entered the market channel with the following characteristics:

GRADE FACTORS AND MOISTURE

- Average test weight of 57.9 lb/bu (74.5 kg/hl), with 94% above the minimum limit for U.S. No. 2 grade sorghum.
- Low levels of BNFM (average of 1.4%), with 92% below the maximum limit for U.S. No. 1 grade.
- Average foreign material of 0.5%, well below the maximum limit for U.S. No. 1 grade, indicating little cleaning will be required.
- Low levels of total damage (average of 0.2%), with 96% below the maximum limit for U.S. No. 1 grade.
- No observed heat damage, which was expected for farm-originated samples.
- Average elevator moisture of 14.5%, near optimum for harvest moisture.

CHEMICAL COMPOSITION

- Average protein concentration of 10.4% (dry basis), which is on the lower end of typical protein concentration values in literature for U.S. sorghum hybrids.
- Average starch concentration of 73.3% (dry basis), a typical level for any sorghum samples.
- Average oil concentration of 4.3% (dry basis), which is on the higher end of typical oil concentration values in literature for U.S. sorghum hybrids.
- No detected levels of tannins.

PHYSICAL FACTORS

- Average kernel diameter of 2.54 mm and average kernel volume of 19.22 mm^3, typical values for any sorghum samples.
- A 1000-k weight average (25.97 g), on the lower end of typical values in literature.
- Average kernel true density of 1.350 g/cm^3, which is within the range of feed sorghum.
- Average kernel hardness index of 68.5, a typical value for any sorghum samples.

II. INTRODUCTION

The *U.S. Grains Council 2015/2016 Sorghum Early Harvest Quality Report* and *2015/2016 Sorghum Harvest and Export Cargo Quality Report* are designed to help international buyers of U.S. sorghum understand the quality of U.S. commodity sorghum as it enters the merchandising channel at harvest and as it is assembled for export early in the marketing year. These reports will provide representative information about quality levels and variability at the point of origination, either at harvest or at export. Inbound, unblended commodity samples are collected at local grain elevators for the harvest sampling, while export cargo samples of commodity sorghum are collected at key export areas. This *2015/2016 Early Harvest Report* is based on 50 commodity sorghum samples taken from defined areas within the top 2015 sorghum-producing and exporting states that harvested sorghum in August and September, 2015. This report takes an early look at the quality of the 2015 sorghum crop and sets the foundation for the quality of the entire 2015 sorghum crop that will be reported in the *2015/2016 Sorghum Harvest and Export Cargo Quality Report*.

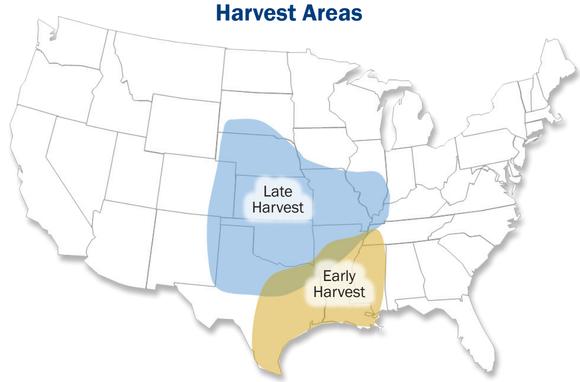
The sample collection and testing, as well as the results reporting, of the sorghum harvest quality in the *Early Harvest Report* and *Harvest and Export Cargo Report* were modeled after the survey and report designs implemented for the U.S. Grains Council's *Corn Harvest Quality Report*. The sorghum harvest samples were proportionately stratified according to Agricultural Statistical Districts (ASDs) across the key 2015 sorghum-producing states. This was to ensure a sound statistical sampling of the U.S. sorghum crop at the first stage of the market channel.

The sorghum harvest samples were tested for the following quality factors:

- Grade Factors: test weight, broken kernels and foreign material (BNFM), foreign material, total damage, and heat damage
- Moisture
- Chemical Composition: protein, starch, oil, and tannins
- Physical Factors: kernel diameter, 1000-kernel weight, kernel volume, kernel true density, and kernel hardness index

Weighted averages and standard deviations following standard statistical techniques for proportionate stratified sampling were calculated for each of the quality factors. The results from the 50 early harvest samples are reported as "Early Harvest" in the "Quality Test Results" section of this *Early Harvest Report* while the results of the entire 2015 sorghum harvest ("Early Harvest," "Late Harvest," and "U.S. Aggregate") will be reported in the *Harvest and Export Cargo Report*.

Harvest Areas



Overall, this *Early Harvest Report* indicates the 2015 Early Harvest sorghum is entering the 2015/2016 market channel with average grade factor levels exceeding the standards for U.S. No. 1 grade sorghum. In addition, oil concentration was at the higher end of sorghum levels found in literature, no noticeable tannin levels were found among the 50 survey samples, and typical values were found for kernel volume, true density and kernel hardness. While these quality characteristics establish an early look at the quality of the 2015 U.S. sorghum crop, the quality reported in the *Harvest and Export Cargo Report* will reflect the quality of the entire 2015 crop. As sorghum quality from the Late Harvest area is surveyed, the impact of the environment, genetics and growing season conditions across both of the two harvest areas may alter the U.S. Aggregate averages from the Early Harvest averages.

II. INTRODUCTION (continued)

Along with an evaluation of the quality of the entire 2015 sorghum crop and early exports, the *2015/2016 Sorghum Harvest and Export Cargo Quality Report* will include an assessment of the crop and weather conditions during the 2015 growing season; U.S. sorghum production, usage and outlook; and detailed descriptions of survey and statistical analysis methods, and testing methods.

This first year of sorghum quality data will lay the foundation for evaluating trends and the factors that impact sorghum quality. In addition, the cumulative measurement surveys will increase in value by enabling export buyers to make year-to-year comparisons and assess patterns of sorghum quality based on crop growing conditions across the years.

III. QUALITY TEST RESULTS

A. Grade Factors

The U.S. Department of Agriculture's Federal Grain Inspection Service (FGIS) has established numerical grades, definitions and standards for grains. The attributes which determine the numerical grades for sorghum are test weight, broken kernels and foreign material (BNFM), foreign material, total damage, and heat damage. The table for "U.S. Sorghum Grades and Grade Requirements" is provided on page 28 of this report.

SUMMARY: GRADE FACTORS AND MOISTURE

- *Early Harvest average test weight in 2015 was 57.9 lb/bu (74.5 kg/hl), above the minimum for U.S. No. 1 grade sorghum (57 lb/bu or 73.4 kg/hl).*
- *The 2015 Early Harvest test weight values were distributed with 94% of the samples at or above the limit for U.S. No. 2 grade (55 lb/bu or 70.8 kg/hl).*
- *Early Harvest average BNFM in the 2015 samples (1.4%) was well below the maximum for U.S. No. 1 grade (3.0%).*
- *The 2015 Early Harvest BNFM values were all below the maximum for U.S. No. 2 grade (6%).*
- *Early Harvest average foreign material in the 2015 samples (0.5%) was well below the maximum for U.S. No. 1 grade (1.0%).*
- *In the 2015 Early Harvest samples, 98% contained less than the maximum foreign material allowable for U.S. No. 2 grade (2.0%).*
- *Early Harvest average total damage in the 2015 samples (0.2%) was well below the maximum for U.S. No. 1 grade (2.0%).*
- *Total damage in the 2015 Early Harvest samples was distributed with 98% having 5% or less (the maximum allowable for U.S. No. 2 grade).*
- *There was no heat damage observed in any of the 2015 Early Harvest samples.*
- *The absence of heat damage likely was due in part to recently-harvested samples coming directly from farm to elevator with minimal prior drying.*
- *The Early Harvest moisture contents recorded at the elevator in the 2015 samples averaged 14.5% with a minimum value of 11.7% and a maximum value of 17.3%.*

III. QUALITY TEST RESULTS (continued)

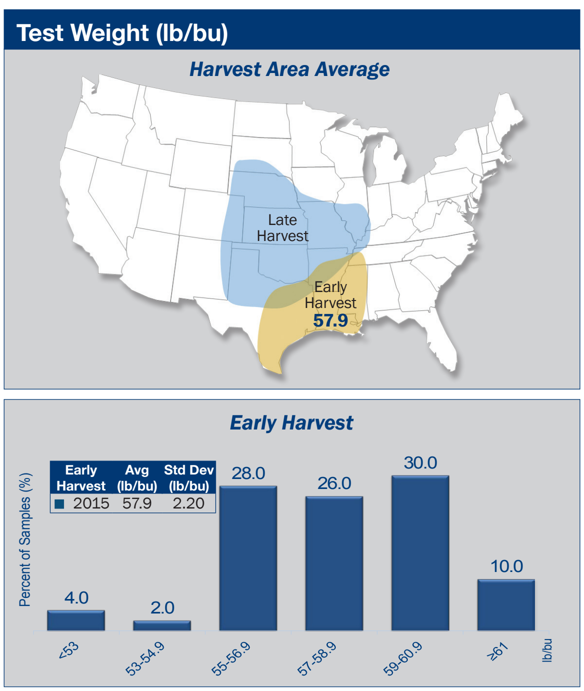
1. Test Weight

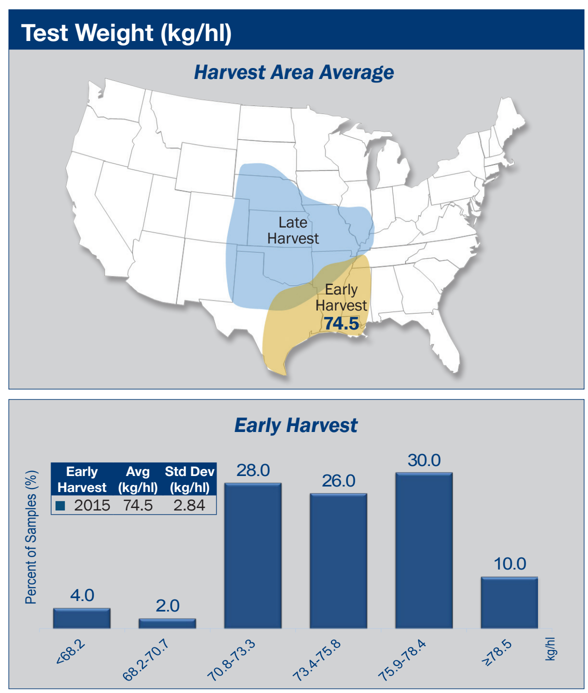
U.S. Grade Minimum Test Weight
No. 1: 57.0 lbs
No. 2: 55.0 lbs
No. 3: 53.0 lbs

Test weight (kernel weight per standard container 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 size reduction and value-added processing. High test weight sorghum will take up less storage space than the same weight of sorghum 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 hard (or vitreous) endosperm and sound, clean sorghum. Test weight is highly correlated with kernel true density and reflects kernel hardness and kernel maturity.

RESULTS

- Early Harvest average test weight in 2015 was 57.9 lb/bu (74.5 kg/hl), above the minimum for U.S. No. 1 grade (57 lb/bu or 73.4 kg/hl).
- The test weight values for the 2015 Early Harvest samples had a standard deviation of 2.20 lb/bu (2.84 kg/hl).
- The 2015 Early Harvest test weight values were distributed with 66% of the samples at or above the factor limit for U.S. No. 1 grade and 94% of the samples at or above the limit for U.S. No. 2 grade (55 lb/bu or 70.8 kg/hl).





2. Broken Kernels and Foreign Material (BNFM)

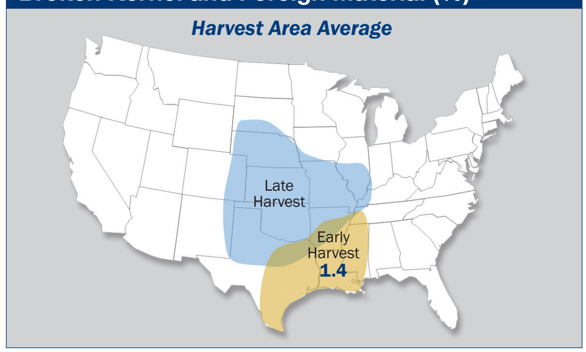
Broken kernels and foreign material (BNFM) is an indicator of the amount of clean, sound sorghum available for feed and processing. The lower the percentage of BNFM, the less foreign material and/or fewer broken kernels are in a sample. Higher levels of BNFM in farm-originated samples generally stem from combine settings and/or weed seeds in the field. BNFM levels will normally increase during drying and handling, depending on the methods used and the soundness of the kernels. Stress crack formation during dry down or during mechanical drying after harvest will also result in an increase in broken kernels and BNFM during subsequent handling.

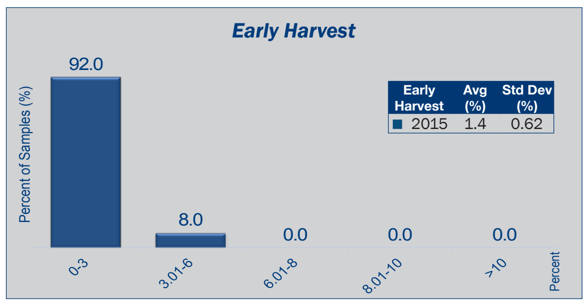
U.S. Grade BNFM Maximum Limits
No. 1: 3.0%
No. 2: 6.0%
No. 3: 8.0%

RESULTS

- Early Harvest average BNFM in the 2015 samples (1.4%) was well below the maximum for U.S. No. 1 grade (3.0%).
- The BNFM values for the 2015 Early Harvest samples had a standard deviation of 0.62%.
- The 2015 Early Harvest BNFM values were all below the maximum for U.S. No. 2 grade (6%), with 92% of the samples also below the maximum for U.S. No. 1 grade (3%).

Broken Kernel and Foreign Material (%)





III. QUALITY TEST RESULTS (continued)

3. Foreign Material

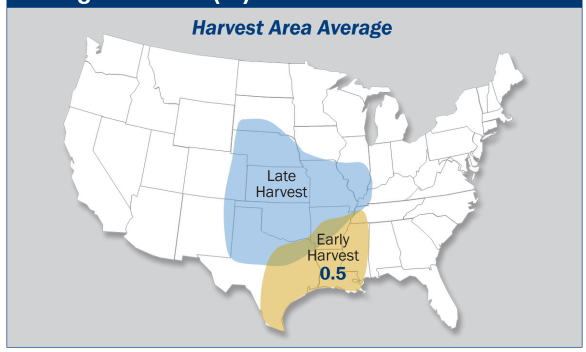
Foreign material, a subset of BNFM, is of importance because it has little feed or processing value. It is also generally higher in moisture content than the sorghum and therefore creates a potential for deterioration of sorghum quality during storage. Foreign material also contributes to the spoutline and has the possibility of creating more quality problems and damage because of its higher moisture level, as mentioned above.

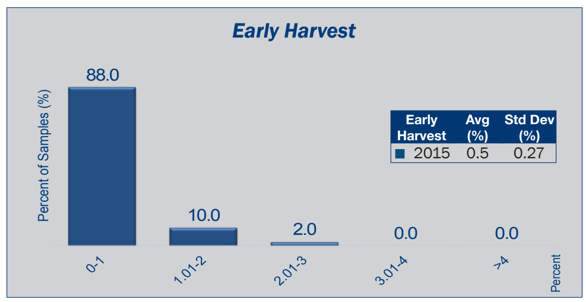
U.S. Grade FM Maximum Limits
No. 1: 1.0%
No. 2: 2.0%
No. 3: 3.0%

RESULTS

- Foreign material in the Early Harvest samples averaged 0.5% in 2015, well below the maximum value of 1.0% for U.S. No. 1 grade.
- The foreign material values for the 2015 Early Harvest samples had a standard deviation of 0.27%.
- In the 2015 Early Harvest samples, 98% of the samples contained less than the maximum foreign material allowable for U.S. No. 2 grade (2.0%).

Foreign Material (%)





4. Total Damage

Total damage is the percentage of kernels and pieces of kernels that are visually damaged in some way, including badly ground-damaged, badly weather-damaged, diseased, frost-damaged, germ-damaged, heat-damaged, insect-bored, mold-damaged, sprout-damaged, or otherwise materially damaged. 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.

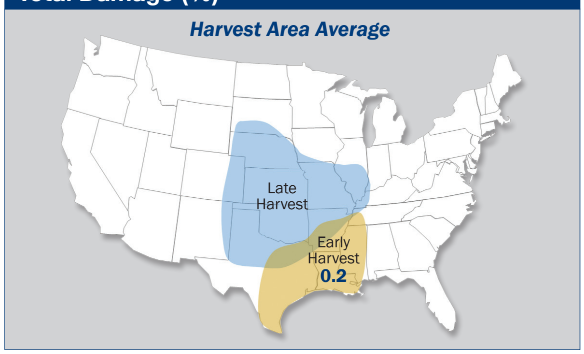
U.S. Grade Total Damage Maximum Limits
No. 1: 2.0%
No. 2: 5.0%
No. 3: 10.0%

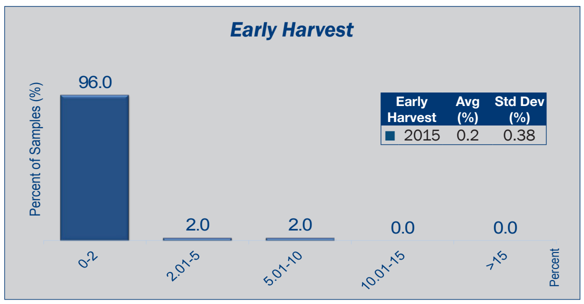
Mold damage is usually associated with higher than desired moisture contents and temperatures during growth and/or in storage. Mold damage and the associated potential for development of mycotoxins are the damage factors of greatest concern. Mold damage can occur prior to harvest as well as during temporary storage at high moisture and high temperature levels before delivery.

RESULTS

- Total damage in the Early Harvest samples averaged 0.2% in 2015, well below the limit for U.S. No. 1 grade (2%).
- The total damage values for the 2015 Early Harvest samples had a standard deviation of 0.38%.
- Total damage in the 2015 Early Harvest samples was distributed with 96% of the samples having 2% or less damaged kernels (the maximum allowable for U.S. No. 1 grade), and 98% having 5% or less (the maximum allowable for U.S. No. 2 grade).

Total Damage (%)





5. 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 sorghum delivered at harvest directly from farms.

RESULTS

- There was no heat damage observed in any of the samples.
- The absence of heat damage likely was due in part to recently-harvested samples coming directly from farm to elevator with minimal prior drying.

U.S. Grade Heat Damage Maximum Limits
No. 1: 0.2%
No. 2: 0.5%
No. 3: 1.0%

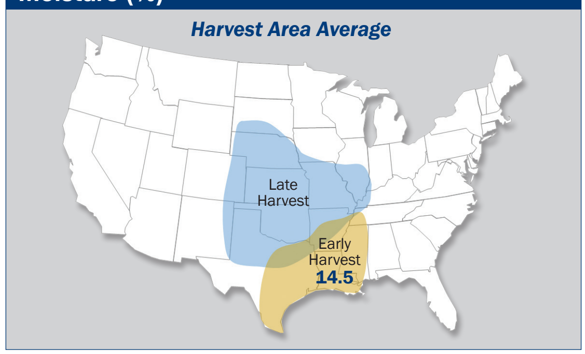
B. Moisture

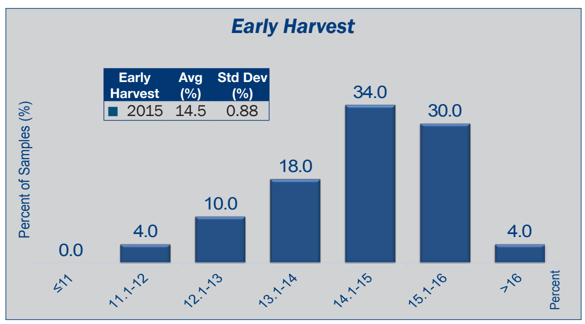
Moisture content (water weight in kernels per total weight of kernels (i.e., water plus dry matter)) is reported on official grade certificates, but does not determine which numerical grade will be assigned to the sample. Moisture content affects the amount of dry matter being sold and purchased. Moisture is also an indicator for potential drying, has potential implications for storability, and affects test weight. Higher moisture content at harvest increases the chance of kernel damage occurring during harvesting and drying. Moisture content and the amount of mechanical drying required will also affect stress crack formation, breakage, and germination. Extremely wet kernels may be a precursor to high mold damage later in storage or transport. While the weather during the growing season affects yield and the development of the kernels, harvest moisture is influenced largely by the timing of harvest and harvest weather conditions.

RESULTS

- The Early Harvest moisture contents recorded at the elevator in the 2015 samples averaged 14.5%, with a minimum value of 11.7% and a maximum value of 17.3%.
- The moisture content values for the 2015 Early Harvest samples had a standard deviation of 0.88%.
- The 2015 moisture values were distributed with only 32% of the samples containing 14% or less moisture. This is the base moisture used by most elevators for discounts and is a level considered safe for storage for short periods during low winter-time temperatures. Drying may have been considered for 68% of the 2015 Early Harvest samples.

Moisture (%)





SUMMARY: GRADE FACTORS AND MOISTURE

2015 Early Harvest	No. of Samples	Avg.	Std. Dev.	Min.	Max.
Grade Factors and Moisture					
Test Weight (lb/bu)	50	57.9	2.20	46.3	62.0
Test Weight (kg/hl)	50	74.5	2.84	59.6	79.8
BNFM (%)	50	1.4	0.62	0.5	4.5
Foreign Material (%)	50	0.5	0.27	0.1	2.1
Total Damage (%)	50	0.2	0.38	0.0	5.7
Heat Damage (%)	50	0.0	0.00	0.0	0.0
Moisture (%)	50	14.5	0.88	11.7	17.3

C. Chemical Composition

Chemical composition of sorghum is important because the components of protein, starch, oil and tannins are of significant interest to end users. The chemical composition attributes are not grade factors. However, they provide additional information related to nutritional value for livestock and poultry feeding and other processing uses of sorghum. Unlike many physical attributes, chemical composition values are not expected to change significantly during storage or transport.

SUMMARY: CHEMICAL COMPOSITION

- *In 2015, Early Harvest protein concentration averaged 10.4%, which is on the lower end of typical protein concentration values in literature for U.S. sorghum hybrids.*
- *Early Harvest starch concentration averaged 73.3% in 2015, a typical level for any sorghum samples.*
- *Early Harvest oil concentration averaged 4.3% in 2015, which is on the higher end of typical oil concentration values in literature for U.S. sorghum hybrids.*
- *Early Harvest oil concentration in 2015 was bimodally distributed with 40% of samples at 3.99% or lower and 50% of samples at 4.5 to 4.99%.*
- *All 2015 Early Harvest samples were considered tannin-free.*

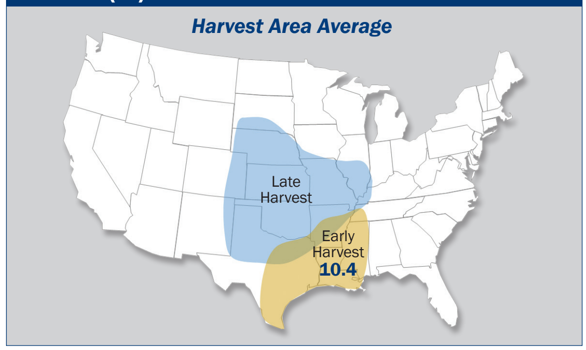
1. Protein

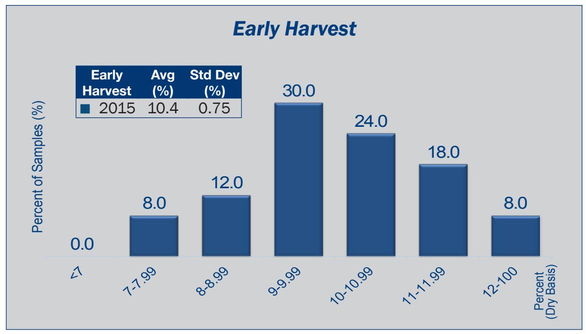
Protein is very important for poultry and livestock feeding. It supplies essential sulfur-containing amino acids and helps to improve feed conversion efficiency. Protein is usually inversely related to starch concentration. Results are reported on a dry basis.

RESULTS

- In 2015, Early Harvest protein concentration averaged 10.4%, which is on the lower end of typical protein concentration values in literature for U.S. sorghum hybrids.
- The protein concentration values for the 2015 Early Harvest samples had a standard deviation of 0.75%.
- Protein concentration range for the Early Harvest samples was from 7.1 to 12.7% in 2015.
- Protein concentration in the 2015 Early Harvest samples was distributed with 20% of samples below 9.0%, 54% between 9.0 and 10.99%, and only 26% at or above 11.0%.

Protein (%)





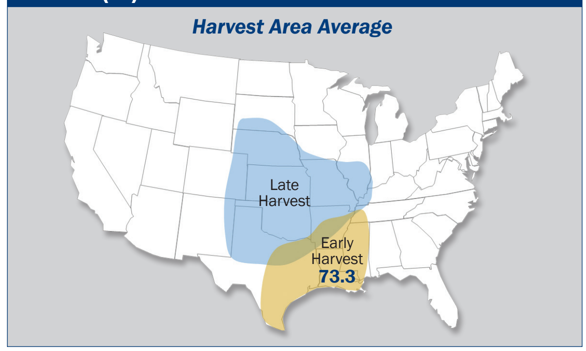
2. Starch

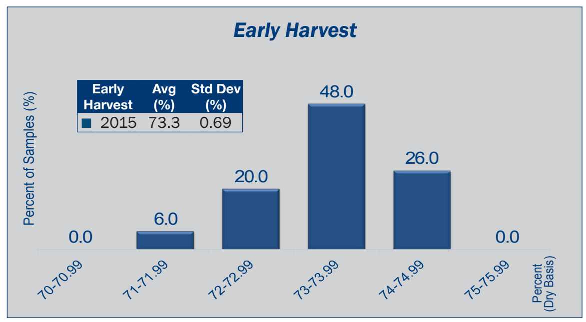
Starch is an important factor for sorghum related to metabolizable energy for livestock and poultry. Levels of starch in sorghum may also be of interest to processors as starch provides the substrate for several value-added processes. High starch concentration is often indicative of good kernel maturation/filling conditions and reasonably moderate kernel densities. Starch is usually inversely related to protein concentration. Results are reported on a dry basis.

RESULTS

- Early Harvest starch concentration averaged 73.3% in 2015, a typical level for any sorghum samples.
- The starch concentration values for the 2015 Early Harvest samples had a standard deviation of 0.69%.
- Starch concentration range for the Early Harvest samples was from 71.1 to 75.0% in 2015.
- Starch concentration in the 2015 Early Harvest samples was distributed with 26% of samples between 70.0 and 72.99%, 48% between 73.0 and 73.99%, and 26% equal to or greater than 74.0%.

Starch (%)





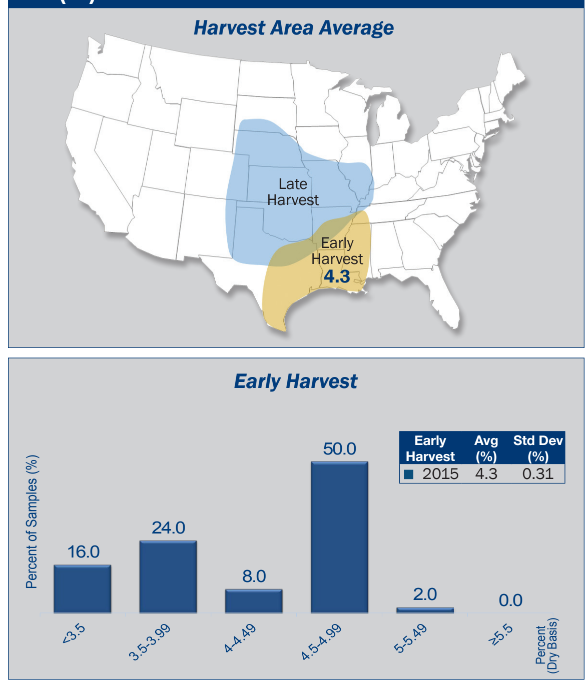
3. Oil

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 may also be an important co-product of sorghum value-added processing. Results are reported on a dry basis.

RESULTS

- Early Harvest oil concentration averaged 4.3% in 2015, which is on the higher end of typical oil concentration values in literature for U.S. sorghum hybrids.
- The oil concentration values for the 2015 Early Harvest samples had a standard deviation of 0.31%.
- Oil concentration range for the Early Harvest samples was from 3.0 to 5.0% in 2015.
- Early Harvest oil concentration in the 2015 Early Harvest samples was bimodally distributed with 40% of samples at 3.99% or lower and 50% of samples at 4.5 to 4.99%. Additionally, 8% of samples had oil concentrations from 4.0 to 4.49% and 2% were at 5.0% and higher.
- The samples with oil concentrations greater than 4.25% were confined to one area within the Early Harvest sampling area.

Oil (%)

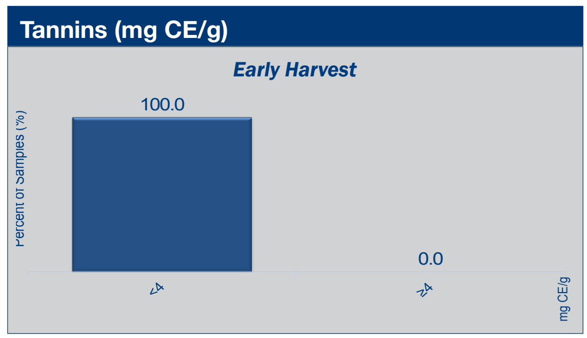


4. Tannins

Tannins are present in sorghum varieties that have a pigmented testa within their kernels. Chemically, tannins are compounds that are large molecules comprised of smaller molecules (catechins and epicatechins) and belong to a broader class of compounds called proanthocyanidins (compounds found in grapes, bark, tea leaves, etc. that influence aroma, flavor, mouth-feel and astringency, and have antioxidant and other possible health benefits). While present in sorghum varieties grown around the world, more than 99% of sorghum currently grown in the United States is tannin-free due to decades of breeding efforts to eliminate tannins from sorghum hybrids. Tannins have effects on nutritional and functional properties as a result of interactions of the tannins with other kernel chemicals. Livestock and poultry growth performance is negatively affected by presence of tannins in sorghum-containing rations. Current non-tannin sorghums grown in the United States have virtually the same energy profile as corn in feed rations. Results are reported as being below 4.0 milligrams of catechin equivalents (CE) per gram sample or 4.0 mg CE/g or above. Values below 4.0 mg CE/g generally imply absence of condensed tannins[1, 2].

RESULTS

- All observed tannin levels in the 2015 Early Harvest samples were less than 4.0 mg CE/g, implying an absence of tannins.



[1]Awika, J.M., L.W. Rooney, 2004. Sorghum phytochemicals and their potential impact on human health. Phytochemistry 65, 1199-1221.

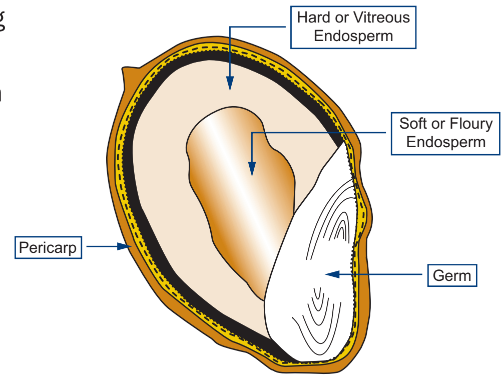
[2]Price, Martin L., Van Scoyoc, S., Butler, L.G., 1978. A critical evaluation of vanillin reaction as an assay for tannin sorghum. Journal of Agricultural and Food Chemistry 26, 1214-1218.

SUMMARY: CHEMICAL COMPOSITION

2015 Early Harvest					
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
Chemical Composition					
Protein (Dry Basis %)	50	10.4	0.75	7.1	12.7
Starch (Dry Basis %)	50	73.3	0.69	71.1	75.0
Oil (Dry Basis %)	50	4.3	0.31	3.0	5.0

D. Physical Factors

Physical factors include other quality attributes that are neither grading factors nor chemical composition. Tests for physical factors provide additional information about the processing characteristics of sorghum for various uses, as well as its storability and potential for breakage in handling. The storability, the ability to withstand handling, and the processing performance of sorghum are influenced by sorghum's morphology. Sorghum kernels are morphologically made up of three parts, the germ or embryo, the pericarp or outer covering, and the endosperm. The endosperm represents about 82 to 86% of the kernel, and consists of soft (also referred to as floury) endosperm and of hard (also called vitreous) endosperm, as shown to the right. The endosperm contains primarily starch and protein whereas the germ contains oil and some proteins. The pericarp is comprised mostly of fiber with a small coating of waxy material.



Adapted from Rooney and Miller 1982

SUMMARY: PHYSICAL FACTORS

- *For the Early Harvest sorghum samples in 2015, kernel diameter averaged 2.54 mm, 1000-k weights averaged 25.97 g and kernel volume averaged 19.22 mm^3, all typical values for kernels from any sorghum samples, except 1000-k weights which are on the lower end of typical values cited in literature.*
- *In the 2015 Early Harvest samples, kernel true densities averaged 1.350 g/cm^3, which is within the range of feed sorghum.*
- *Kernel hardness index averaged 68.5 for Early Harvest sorghum in 2015, a typical value for any sorghum sample.*

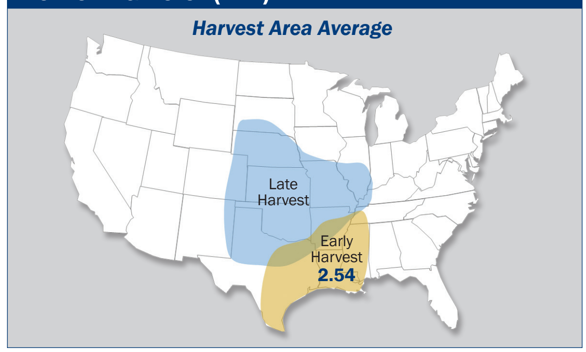
1. Kernel Diameter

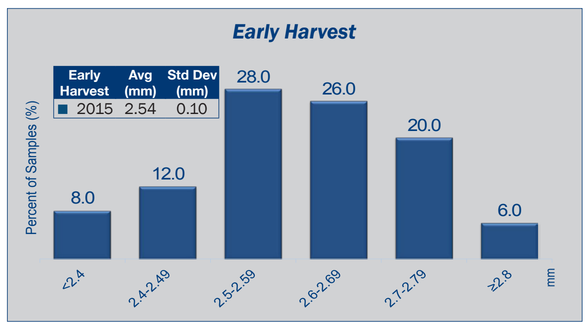
Kernel diameter directly correlates with kernel volume, affects size reduction behavior and material handling practices, and may indicate maturity of kernels. Size reduction refers to reducing kernels (large particles) to ground material (small particles), commonly through grinding/milling. Size reduction, energy consumption, decortication efficiency and yield of kernel components depend on diameter. Decortication refers to the removal of the pericarp and germ from a kernel by attrition or abrasion with minimal removal of endosperm before subsequent grinding/milling. The smaller the kernels, the more care and concern required in handling. Incomplete kernel fill and unexpected weather conditions may contribute to small diameter values.

RESULTS

- Kernel diameter averaged 2.54 mm for Early Harvest sorghum in 2015, a typical value for any sorghum samples.
- The kernel diameter values for the 2015 Early Harvest samples had a standard deviation of 0.10 mm.
- Kernel diameters for the Early Harvest samples ranged from 2.20 to 2.90 mm in 2015.
- In 2015, Early Harvest kernel diameters were distributed so that 26% of the samples had kernel diameters of 2.7 mm or greater, 54% were between 2.5 and 2.69 mm, and 20% were less than 2.5 mm.

Kernel Diameter (mm)





III. QUALITY TEST RESULTS (continued)

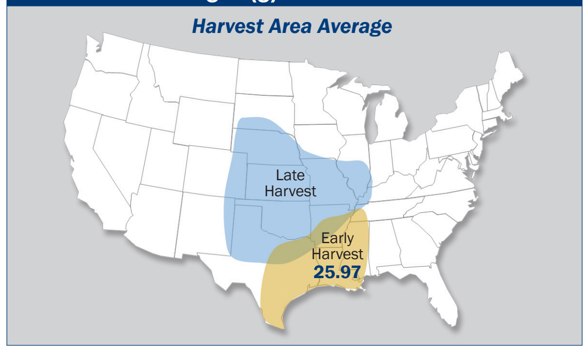
2. 1000-Kernel Weight

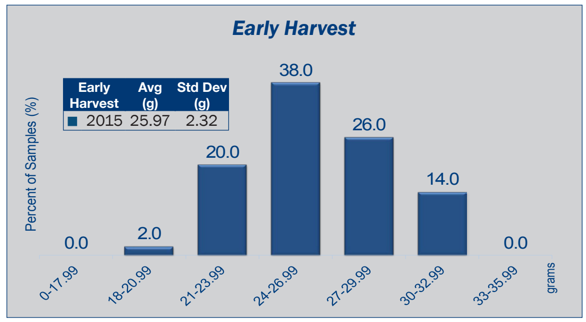
1000-kernel (1000-k) weight is the weight for a fixed number of kernels. Kernel volume (or size) can be inferred from 1000-k weight, since as 1000-k weight increases or decreases, kernel volume will proportionally increase or decrease. Kernel volume affects drying rates. As kernel volume increases, the volume-to-surface-area ratio for the kernel becomes greater, and drying time to a desired moisture takes longer. Kernel weights tend to be higher for specialty varieties of sorghum that have high amounts of hard (vitreous) endosperm.

RESULTS

- 1000-k weights averaged 25.97 g for Early Harvest sorghum in 2015, a value on the lower end of typical 1000-k weight values in literature for U.S. sorghum hybrids.
- The 1000-k weight values for the 2015 Early Harvest samples had a standard deviation of 2.32 g.
- 1000-k weights for the Early Harvest samples ranged from 19.50 to 32.10 g in 2015.
- In the 2015 Early Harvest samples, 1000-k weights were distributed so that 14% of the samples had 1000-k weights of 30.00 g or greater, 64% had between 24.00 and 29.99 g, and 22% less than 24 g.

1000-Kernel Weight (g)



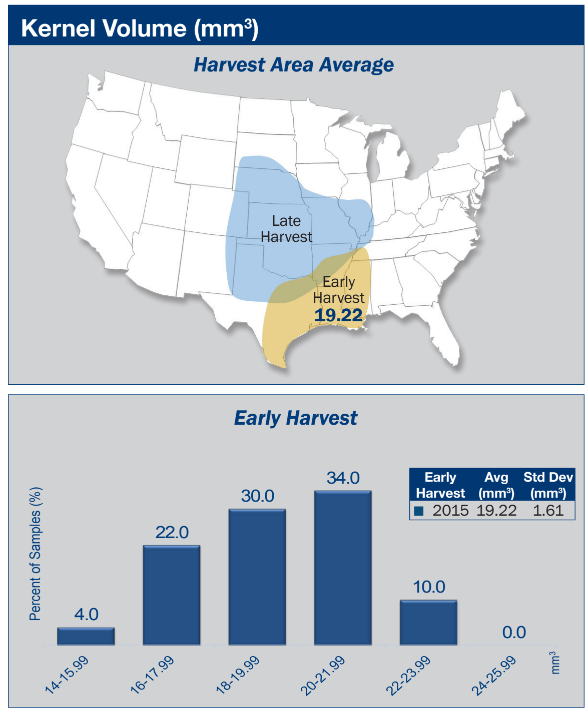


3. Kernel Volume

Kernel volume (or size) is directly related to kernel diameter and often indicative of growing conditions. If conditions are dry, kernels may be small due to stunted development. If drought hits later in the season, kernels may have lower fill. Small kernels are more difficult to handle and, due to their having a greater surface-area-to-volume ratio than large kernels, greater amounts of endosperm are removed during decortication, reducing yield of endosperm-derived products.

RESULTS

- Kernel volume averaged 19.22 mm^3 for Early Harvest sorghum in 2015, a typical value for any sorghum samples.
- The kernel volume values for the 2015 Early Harvest samples had a standard deviation of 1.61 mm^3.
- Kernel volumes for the Early Harvest samples ranged from 14.56 to 23.46 mm^3 in 2015.
- In the 2015 Early Harvest samples, kernel volumes were distributed so that 26% of the samples had kernel volumes of less than 18.0 mm^3, 64% were between 18.0 and 21.99 mm^3, and 10% equal to or greater than 22.0 mm^3.



III. QUALITY TEST RESULTS (continued)

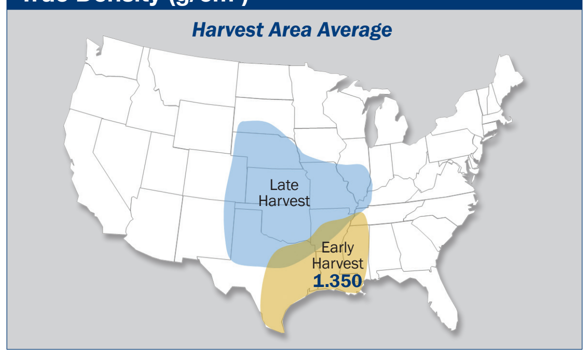
4. Kernel True Density

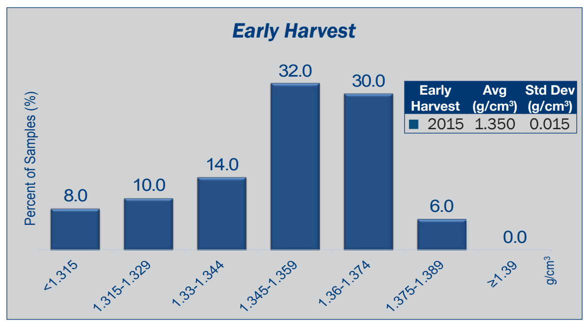
Kernel true density (kernel weight per kernel volume) is a relative indicator of kernel hardness, which is useful during size reduction operations. Genetics of the sorghum hybrid and the growing environment affect kernel true density. Sorghum with higher density is typically less susceptible to breakage in handling than lower-density sorghum. Most feed sorghum has true density values ranging from 1.330 to 1.400 g/cm^3. Sorghum with density greater than 1.315 g/cm^3 is judged suitable for processing to brewers' grits and stiff porridge whereas sorghum with density less than 1.315 g/cm^3 is suitable for processing into soft bread flour and starch.

RESULTS

- Kernel true density averaged 1.350 g/cm^3 for U.S. Early Harvest sorghum in 2015.
- The true density values for the 2015 Early Harvest samples had a standard deviation of 0.015 g/cm^3.
- True densities for the 2015 Early Harvest samples ranged from 1.295 to 1.382 g/cm^3 in 2015.
- In the 2015 Early Harvest samples, kernel true densities were distributed so that 8% of the samples were below 1.315 g/cm^3, 10% between 1.315 and 1.329 g/cm^3, and 82% greater than or equal to 1.330 g/cm^3 and less than 1.390 g/cm^3.

True Density (g/cm^3)



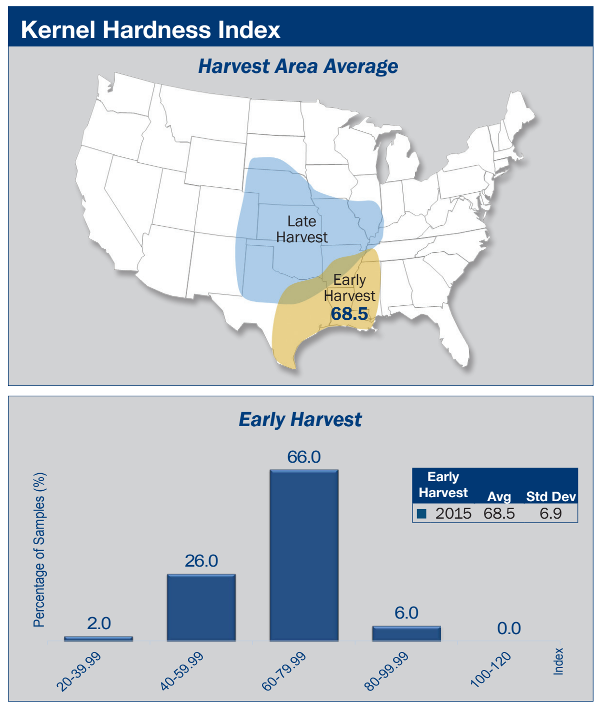


5. Kernel Hardness Index

Kernel hardness affects resistance to molds and insects, size reduction behavior and the end use of sorghum. Sieving behavior, size reduction energy consumption, particle size distribution of ground material and yield of kernel components depend on hardness. Harder sorghum produces coarser or larger particles than softer sorghum and requires more energy per mass of sorghum to achieve similar particle size distribution during size reduction. Grinding/milling for optimum particle size for livestock or poultry feed may be costlier for harder sorghum than for softer sorghum. Test weight and kernel density correlate with hardness. Kernel hardness index is a dimensionless number with increasing value indicating kernels increasing in physical hardness.

RESULTS

- Kernel hardness index averaged 68.5 for Early Harvest sorghum in 2015, a typical value for any sorghum sample.
- The kernel hardness index values for the 2015 Early Harvest samples had a standard deviation of 6.9.
- Kernel hardness index for the Early Harvest samples ranged from 37.1 to 84.0 in 2015.
- In the 2015 Early Harvest samples, kernel hardness indices were distributed so that 6% of the samples had kernel hardness indices of 80.0 or greater, 92% had 40.0 to 79.99, and 2% had less than 40.



III. QUALITY TEST RESULTS (continued)

SUMMARY: PHYSICAL FACTORS

2015 Early Harvest					
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
Physical Factors					
Kernel Diameter (mm)	50	2.54	0.10	2.20	2.90
1000-Kernel Weight (g)	50	25.97	2.32	19.50	32.10
Kernel Volume (mm^3)	50	19.22	1.61	14.56	23.46
True Density (g/cm^3)	50	1.350	0.015	1.295	1.382
Kernel Hardness Index	50	68.5	6.9	37.1	84.0

VII. TESTING ANALYSIS METHODS

The sorghum samples (each about 2500 grams) were sent directly from the local grain elevators to the Cereal Quality Lab (CQL) in the Department of Soil and Crop Sciences, Texas A&M, College Station, Texas. Upon arrival, the samples were dried, if needed, to a suitable moisture content to prevent any subsequent deterioration during the testing period. The samples were then split into two 1100 to 1250-gram subsamples using a Boerner divider. The divider splits the complete sample into two while keeping the attributes of the grain sample evenly distributed between the two subsamples. One subsample was shipped to Amarillo Grain Exchange (AGE) in Amarillo, Texas for grading and mycotoxin testing. AGE is an official grain inspection service provider in Texas 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 CQL for chemical composition and other physical factors following either industry norms or well-established procedures in practice for many years.

A. Sorghum Grading Factors

1. Test Weight

Test weight is a measure of the quantity of grain required to fill a specific volume (Winchester bushel). Test weight is a part of the FGIS Official U.S. Standards for Sorghum 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).

2. Broken Kernels and Foreign Material (BNFM)/Foreign Material

Broken kernels and foreign material (BNFM) and foreign material are part of the FGIS Official U.S. Standards for Sorghum.

This test determines the amount of broken kernels and foreign material contained in the sample. Broken kernels is defined as all material which passes through a 5/64th inch triangular-hole sieve and over a 2.5/64th inch round-hole sieve. Foreign material is defined as all material, except sorghum, that remains on top of the 5/64th inch triangular-hole sieve and all matter other than sorghum which passes over the number 6 riddle. Foreign material is reported as a sum of the mechanically separated foreign material as a percent of the dockage-free sample weight and the handpicked foreign material as a percent of the handpicked sample portion weight. BNFM is reported as the sum of broken kernels as a percent of the dockage-free sample weight and the foreign material.

3. Total Damage/Heat Damage

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

A representative working sample of 15 grams of BNFM-free sorghum is visually examined by a properly trained individual for content of damaged kernels. Types of damage include germ-damaged kernels, ground- and/or weather-damaged kernels, diseased kernels, frost-damaged kernels, heat-damaged kernels, insect-bored kernels, mold-damaged kernels (surface and/or internal), mold-like substance, purple-pigment-damaged kernels, 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 sorghum kernels that are materially discolored and damaged by heat. Heat-damaged kernels are determined by a properly trained individual visually inspecting a 15-gram sample of BNFM-free sorghum. 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 rises.

C. Chemical Composition

1. NIR Proximate Analysis – Sorghum

Proximates are the major components of the grain. For sorghum, the NIR Proximate Analysis includes oil content, protein content, and starch content (or total starch). This procedure is nondestructive to the sorghum.

Chemical composition tests for protein, oil, and starch were conducted using approximately a 50-gram sample in a Perten DA 7250 Near-Infrared Reflectance (NIR) instrument. The NIR was calibrated to chemical tests, and the standard error of predictions for protein, oil, and starch were about 0.3%, 0.4%, and 0.5%, respectively. Results are reported on a dry basis (percent of non-water material).

2. Tannins

Leucoanthocyanidins (catechins) and proanthocyanidins (tannins) are a class of flavonoids known as flavonols that react with vanillin in the presence of mineral acids to produce a red color. Vanillin reacts with the flavonols, but other flavonoid compounds can give specific color development. Values near or below 4.0 mg catechin equivalents (CE) per g sample by this method generally imply absence of condensed tannins. Type III tannin sorghums usually have values greater than 8.0 mg CE/g. The test involves grinding approximately 50 g sound seed using a UDY grinder with 1 mm sieve and accurately weighing 0.30 g of this sample for analysis. Extraction and analysis is performed using the vanillin-HCl test with blank subtraction to remove interference by sorghum pigments. Developed color is measured using a UV-Vis spectrophotometer at 500 nm. Standard curve is run using pure catechin. Tests are run in triplicates and the average value is reported as mg CE/g sample on a dry basis.

D. Physical Factors

1. 1000-Kernel Weight, Kernel Volume and Kernel True Density

The 1000-kernel weight is determined from the average weight of 300 individual kernel replicates using the Perten Single Kernel Characterization System (SKCS 4100). The instrument weighs each seed to the nearest 0.01 mg; the instrument automatically calculates the 1000-kernel weight based on the average weight of the 300 individual seeds. The averaged 1000-kernel weight is reported in grams.

The kernel volume for an accurately weighed 80.00 ± 0.05 g kernel sample is calculated using a helium pycnometer and is expressed in mm^3/kernel. The individual kernel volume is obtained by dividing the 1000-kernel weight (g) by the total seed weight (g) used in the pycnometer, and multiplying the recorded pycnometer volume (cm^3) by this factor. The value obtained, cm^3/1000-kernels, is equivalent to mm^3/kernel. Kernel volumes usually range from 12 to 28 mm^3 per kernel for small and large kernels, respectively.

True density of kernel samples is calculated by dividing the mass (or weight) of the 80.00 ± 0.05 g externally sound kernels by the pycnometer volume (displacement) of the same kernels. True density is reported in grams per cubic centimeter (g/cm^3). True densities typically range from 1.24 to 1.39 g/cm^3 at "as is" moistures of about 12 to 15%.

2. Kernel Hardness Index

Grain hardness is measured using the SKCS 4100. The SKCS 4100 automatically picks individual kernels, weighs them, then crushes them between a toothed rotor and a progressively narrowing crescent gap. As a kernel is crushed, the force between the rotor and crescent is measured. About 50 g of clean, externally intact seed is introduced into the instrument hopper. The instrument then automatically characterizes 300 individual seeds. The data are reported as average kernel hardness index, based on the 300 individual seeds. Samples are also classified as hard, mixed, or soft, depending on average hardness index value and hardness distribution among the 300 seeds. Kernel hardness index values can range from 20 to 120.

3. Kernel Diameter

Kernel diameter is measured using the SKCS 4100. The instrument records the individual diameter of 300 seeds, and calculates the average seed diameter in mm.

U.S. SORGHUM GRADES AND CONVERSIONS

U.S. SORGHUM GRADES AND GRADE REQUIREMENTS

		Maximum Limits of			
		Damaged Kernels		Broken Kernels and Foreign Material	
Grade	Minimum Test Weight per Bushel (Pounds)	Heat Damaged (Percent)	Total (Percent)	Foreign Material (part of total) (Percent)	Total (Percent)
U.S. No. 1	57.0	0.2	2.0	1.0	3.0
U.S. No. 2	55.0	0.5	5.0	2.0	6.0
U.S. No. 3[1]	53.0	1.0	10.0	3.0	8.0
U.S. No. 4	51.0	3.0	15.0	4.0	10.0

U.S. Sample Grade is sorghum that: (a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, or 4; or (b) Contains 8 or more stones which have an aggregate weight in excess of 0.2 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, 10 or more rodent pellets, bird droppings, or an equivalent quantity of other animal filth in 1,000 grams of sorghum, 11 or more pieces of other material from any combination of animal filth, castor beans, crotalaria seeds, glass, stones, unknown foreign substances, and cockleburs; or (c) Has a musty, sour, or commercially objectionable foreign odor (except smut odor); or (d) Is badly weathered, heating or otherwise of distinctly low quality.

[1] Sorghum which is distinctly discolored shall not grade any higher than U.S. No. 3.

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

U.S. AND METRIC CONVERSIONS

Sorghum 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

U.S. GRAINS COUNCIL

20 F Street, NW Suite 600
Washington, DC 20001

Phone: +202-789-0789
Fax: +202-898-0522

Email: grains@grains.org
Website: grains.org

People's Republic of China

Beijing
Tel1: +86-10-6505-1314
Tel2: +86-10-6505-2320
Fax: +86-10-6505-0236
grainsbj@grains.org.cn

Egypt

Cairo
Tel: +20-100-1000149
grains@grains.org

Japan

Tokyo
Tel: +81-3-6206-1041
Fax: +81-3-6205-4960
tokyo@grains.org

Korea

Seoul
Tel: +82-2-720-1891
Fax: +82-2-720-9008
seoul@grains.org

Mexico

Mexico City
Tel1: +52-55-5282-0244
Tel2: +52-55-5282-0973
Tel3: +52-55-5282-0977
Fax: +52-55-5282-0969
mexico@grains.org

Middle East and Africa

Tunis
Tel: +216-71-191-640
Fax: +216-71-191-650
tunis@usgrains.net

South and Southeast Asia

Kuala Lumpur
Tel: +603-2093-6826
Fax: +603-2093-2052
grains@grainsea.org

Taiwan

Taipei
Tel1: +886-2-2523-8801
Fax: +886-2-2523-0149
taipei@grains.org

Tanzania

Dar es Salaam
Tel: +255-68-362-4650
mary@usgrainstz.net

Western Hemisphere

Panama City
Tel: +507-315-1008
Fax: +507-315-0503
LTA@grains.org

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