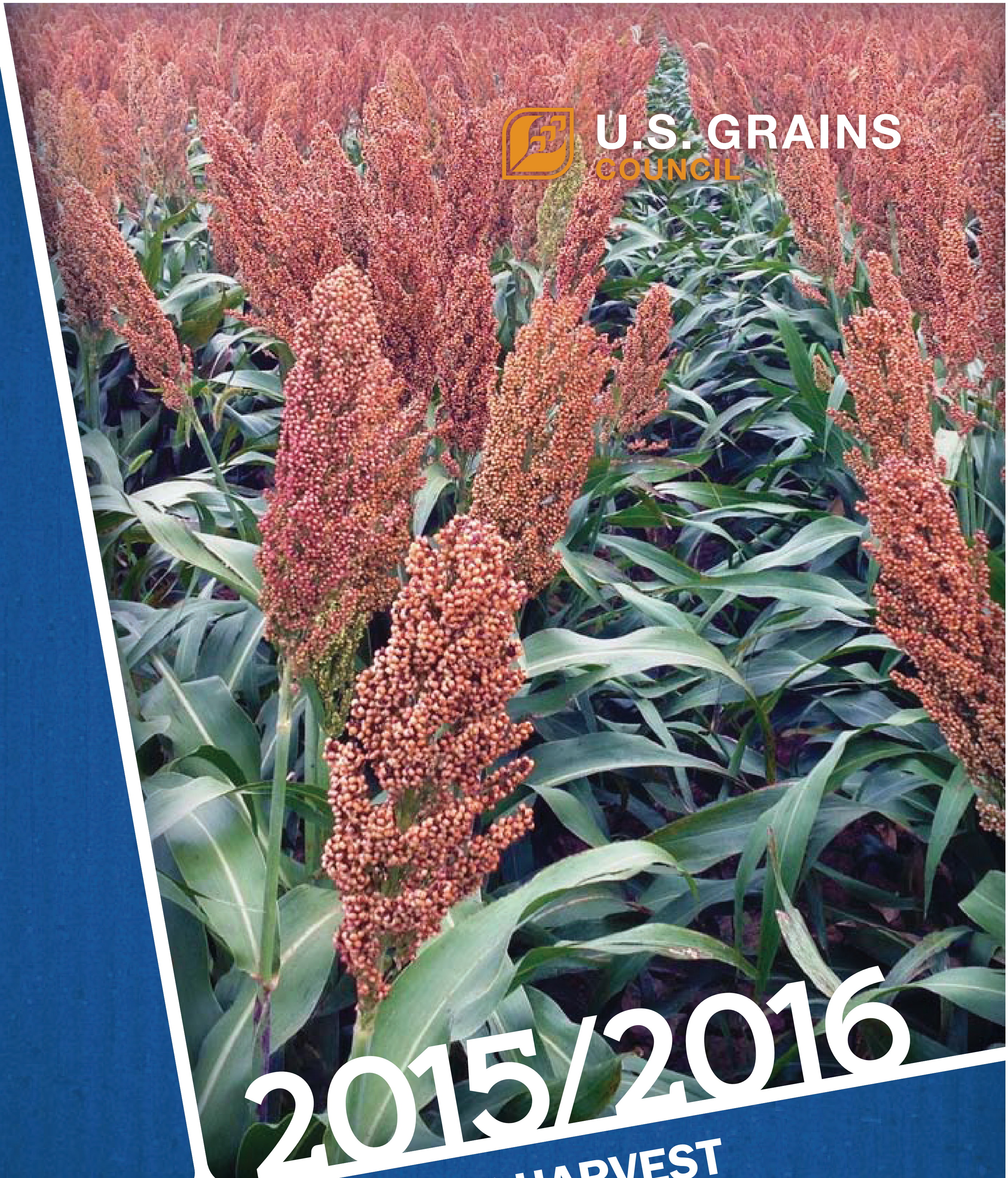

U.S. GRAINS COUNCIL

2015/2016

SORGHUM HARVEST & EXPORT CARGO 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, Ignacio Ciampitti, Tom Whitaker, and Marvin R. Paulsen. In addition, the Council is indebted to the Cereal Quality Lab (CQL) at Texas A&M University and Amarillo Grain Exchange (AGE) for providing the sorghum quality testing services.

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 the harvest samples during their very busy period.

Finally, we acknowledge the irreplaceable services of the Federal Grain Inspection Service (FGIS) of the U.S. Department of Agriculture. FGIS provided samples from export cargoes along with their grading and aflatoxin test results. The FGIS Office of International Affairs coordinated the sampling process, and FGIS field staff collected and submitted the export samples. We are thankful for the time they devoted during their busy season.

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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 Harvest & Export Cargo Quality Report*, the first in a new annual series. This report is a follow-up to the Council's *2015/2016 Sorghum Early Harvest Quality Report,* which provided an early look at the quality of the 2015 sorghum crop as it was harvested in the southern part of the 2015 growing area.

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 sorghum quality report is to offer a transparent view of the United States' most recent sorghum crop's quality as the harvested sorghum comes out of the field and as the sorghum reaches 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.

This *2015/2016 Sorghum Harvest & Export Cargo Quality Report* provides information about sorghum grade quality and other quality factors that have not been reported elsewhere. The value of this report to all stakeholders will increase over time as the information become more familiar and as year-to-year patterns appear. We trust our international customers will find this *2015/2016 Sorghum Harvest & Export Cargo Quality Report* informative and useful, and we look forward to continued engagement based on the information it provides.

Sincerely,

Alan Tiemann
Chairman, U.S. Grains Council
February 2016

I. HARVEST QUALITY HIGHLIGHTS

Due to particularly favorable weather conditions during the growing season, which enabled high yields and increased acreage, the 2015 U.S. sorghum crop is estimated at 15.083 million metric tons (594 million bushels), a 37% increase in production over the 2014 crop and the largest since 1999. The 2015 harvest samples were, on average, very good, with 94% grading U.S. No. 2 or better. Average moisture was near optimum for harvest moisture, no tannins were detected, and the samples' averages for chemical and most physical traits were in the typical range of values in literature for U.S. sorghum. The 2015 U.S. sorghum crop entered the market channel with the following characteristics:

GRADE FACTORS AND MOISTURE

- Average test weight of 58.9 lb/bu (75.9 kg/hl), with 97% at or above the minimum limit for U.S. No. 2 grade sorghum.
- Low levels of broken kernels and foreign material (BNFM) (average of 1.7%), with 91% at or below the maximum limit for U.S. No. 1 grade.
- Average foreign material of 0.6%, well below the maximum limit for U.S. No. 1 grade, indicating little cleaning required.
- Low levels of total damage (average of 0.1%), with 99% 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 14.1%, near optimum for harvest moisture.

CHEMICAL COMPOSITION

- Average protein concentration of 10.9% (dry basis), which is in the range of typical protein concentration values in literature for U.S. sorghum hybrids.
- Average starch concentration of 73.2% (dry basis), a typical level for any sorghum samples.
- Average oil concentration of 4.5% (dry basis), which is in the range of typical oil concentration values in literature for U.S. sorghum hybrids.
- No detected levels of tannins.

PHYSICAL FACTORS

- Average kernel diameter of 2.53 mm and average 1000-k weight (TKW) of 26.30 g, typical values for any sorghum samples.
- Average kernel volume of 19.34 mm^3, a value on the lower end of typical values in literature.
- Average kernel true density of 1.359 g/cm^3, which is within the range of feed sorghum.
- Average kernel hardness index of 71.0, a typical value for any commercial sorghum samples.

MYCOTOXIN

- 100% of the 2015 sorghum harvest samples tested below the FDA action level of 20 ppb.
- 100% of the 2015 sorghum harvest samples tested below the FDA advisory levels for DON (5 ppm for hogs and other animals and 10 ppm for chicken and cattle).

II. EXPORT QUALITY HIGHLIGHTS

The United States is the top exporter of grain sorghum, accounting for almost 75% of the global trade. The 2015/2016 early export samples from the top sorghum exporter were, on average, very good, with 98% grading U.S. No. 2 or better. Average moisture was at a level considered safe for transport, and no tannins were detected. Like the harvest samples, the export samples' averages for chemical and most physical traits were in the typical range of values in literature for U.S. sorghum. Notable U.S. Export Cargo Aggregate quality attributes of the 2015/2016 sorghum early export samples include:

GRADE FACTORS AND MOISTURE

- Average test weight of 59.0 lb/bu (76.0 kg/hl), with 100% above the minimum limit for U.S. No. 2 grade sorghum.
- Low levels of broken kernels and foreign material (BNFM) (average of 1.9%), with 96.2% at or below the maximum limit for U.S. No. 1 grade.
- Average foreign material of 0.9%, with 98.3% at or below the maximum limit for U.S. No. 1 grade.
- Low levels of total damage (average of 0.5%), with 99.5% at or below the maximum limit for U.S. No. 1 grade.
- No observed heat damage, which was the same as for the harvest samples.
- Average moisture of 13.8%.

CHEMICAL COMPOSITION

- Average protein concentration of 10.8% (dry basis), which is in the normal range of typical protein concentration values in literature for U.S. sorghum hybrids.
- Average starch concentration of 73.0% (dry basis), a typical level for any sorghum samples.
- Average oil concentration of 4.5% (dry basis), which is in the normal range of typical oil concentration values in literature for U.S. sorghum hybrids.
- No detected levels of tannins.

PHYSICAL FACTORS

- Average kernel diameter of 2.60 mm and average 1000-k weight (TKW) of 27.57 g, typical values for any sorghum samples.
- Average kernel volume of 20.28 mm^3, a value on the lower end of typical values in literature.
- Average kernel true density of 1.360 g/cm^3, which is within the range of feed sorghum.
- Average kernel hardness index of 71.3, a typical value for any sorghum samples.

MYCOTOXIN

- 100% of the 2015/2016 sorghum export samples tested below the FDA action level of 20 ppb.
- 100% of the 2015/2016 sorghum export samples tested below the FDA advisory levels for DON (5 ppm for hogs and other animals; 10 ppm for chicken and cattle).

III. INTRODUCTION

The *U.S. Grains Council's 2015/2016 Sorghum Harvest & Export Cargo Quality Report* is 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. This report provides representative information about quality levels and variability at the point of origination, either at harvest or at export. The sampling at harvest time is referred to as the *Harvest Survey,* while the sampling of early exports is referred to as the *Export Cargo Survey*. Inbound, unblended commodity samples are collected at local grain elevators for the *Harvest Survey*, while export cargo samples of commodity sorghum are collected at key export areas for the *Export Cargo Survey*.

Abundant rains during the typical planting season occurred across most of the key 2015 sorghum production region, delaying planting progress. The wet conditions that persisted in the southern part of the growing area slowed vegetative development and increased nutrient loss. However, conditions in the northern part of the growing area changed from wet to dry, thereby shortening the grain fill period and accelerating maturity. Dry and warm conditions prevailed and hastened harvest progress across the 2015 U.S. sorghum production area.

Overall, this *2015/2016 Harvest Survey* indicates the 2015 sorghum crop entered the 2015/2016 market channel, with average grade factor levels exceeding the standards for U.S. No. 1 grade sorghum. In addition, sorghum composition was in the typical range of sorghum levels found in literature, no noticeable tannin levels were found among the 207 *Harvest Survey* samples, and typical values were found for true density and kernel hardness.

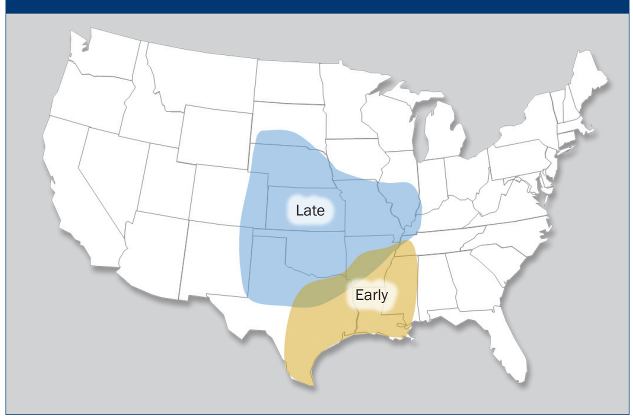
This *2015/2016 Export Cargo Survey* shows the 2015 sorghum crop entered the 2015/2016 export channel with average grade factor levels exceeding the standards for U.S. No. 1 grade sorghum. As with the harvest samples, sorghum composition was in the typical range of sorghum levels found in literature, no noticeable tannin levels were found, and typical values were found for true density and kernel hardness.

This *2015/2016 Harvest Survey* is based on 207 commodity sorghum samples taken from defined areas within nine of the top sorghum-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 nine states are divided into two general groupings that are labeled Harvest Areas (HAs). These two HAs are identified by:

1. The Early Harvest Area, which consists of areas that typically harvest sorghum from the beginning of July through the end of September; and
2. The Late Harvest Area, which consists of areas that typically harvest sorghum from the beginning of September through the end of November or later.

Harvested Area



The sorghum harvest samples are proportionately stratified according to Agricultural Statistical Districts (ASDs) across the key 2015 sorghum-producing states. This is to ensure a sound statistical sampling of the U.S. sorghum crop at the first stage of the market channel. Harvest sample test results are reported at the U.S. Harvest Aggregate level and for the two HAs, providing a general perspective on the geographic variability of U.S. sorghum quality.

III. INTRODUCTION (continued)

The quality characteristics of the sorghum identified at harvest establish the foundation for the quality of the grain ultimately arriving at the export customers' doors. However, as sorghum passes through the U.S. marketing system, it is mingled with sorghum from other locations; aggregated into trucks, barges and railcars; stored; and loaded and unloaded several times. Therefore, the quality and condition of the sorghum change between the initial market entry and the export elevator. For these reasons, the *2015/2016 Harvest Survey* part of this report should be considered carefully in tandem with the *2015/2016 Export Cargo Survey* results that are also included in this report. As always, the quality of an export cargo of sorghum is established by the contract between buyer and seller, and buyers are free to negotiate any quality factor that is particularly important to them.

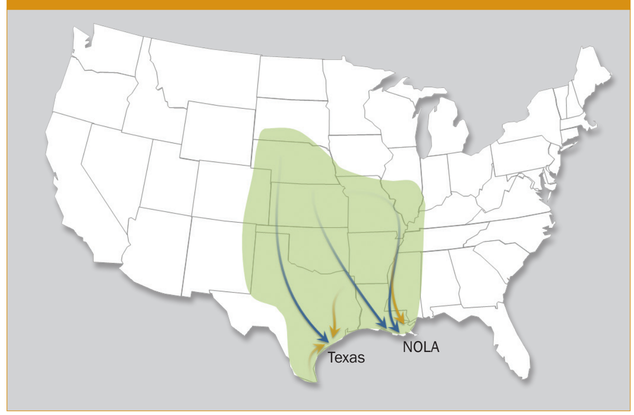
This *2015/2016 Export Cargo Survey* is based on 182 commodity sorghum samples collected from sorghum export shipments as they underwent the federal inspection and grading process performed by the U.S. Department of Agriculture's (USDA) Federal Grain Inspection Service (FGIS).

For the *Export Cargo Survey*, the key sorghum-exporting areas in the United States are divided into two geographical groupings, which we refer to as Export Outlets (EOs). These EOs are identified by the two major pathways to export markets:

1. The Texas EO includes export terminals along the Texas Gulf Coast, primarily League City (Houston Area) and Corpus Christi; and

2. The NOLA EO comprises the export terminals near the Mississippi River Delta.

Export Outlet



The *Export Cargo Survey* samples are proportionately stratified across the two EOs. Export sample test results are reported both at the U.S. Export Aggregate level and for the two EOs.

This report provides detailed information on each of the quality factors tested for both the harvest and export samples. This includes averages and standard deviations for the aggregate of all harvest and export samples, respectively, and for the two HAs and the two EOs. The "Harvest Quality Results" and "Export Quality Results" sections summarize 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 (TKW), kernel volume, kernel true density, and kernel hardness index
- Mycotoxins: aflatoxins and DON

Details about the testing analysis methods used for this report are provided in the "Testing Analysis Methods" section.

The objective of the *Harvest Survey* and *Export Cargo Survey* was to obtain enough samples to estimate quality factor averages of the harvest and export samples with a relative margin of error (Relative ME) of less than ± 10% (a reasonable target for biological data such as these factors). Weighted averages and standard deviations following

III. INTRODUCTION (continued)

standard statistical techniques for proportionate stratified sampling were calculated for each of the quality factors. Details of the statistical sampling and analysis methods are presented in the "Harvest Survey and Statistical Analysis Methods" and "Export Cargo Survey and Statistical Analysis Methods" sections.

Along with an evaluation of the quality of the 2015 sorghum crop and early 2015/2016 exports, the *2015/2016 Sorghum Harvest & Export Cargo Quality Report* includes an assessment of the crop and weather conditions during the 2015 growing season; U.S. sorghum production, usage and outlook; and a description of the U.S. sorghum export system.

This first year of sorghum harvest and export 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 and other stakeholders to begin making year-to-year comparisons and assessing patterns in sorghum quality based on growing, drying, handling, storage, and transport conditions.

The *Export Cargo Survey* does not predict the actual quality of any cargo or lot of sorghum after loading or at destination. It is important for all players in the value chain to understand their own contract needs and obligations, as many of the quality attributes, in addition to grade, can be specified in the buyer-seller contract. In addition, this report does not explain the reasons for changes in quality factors from the *Harvest Survey* to the *Export Cargo Survey*. Many factors, including weather, genetics, commingling, and grain drying and handling, affect changes in sorghum quality in complex ways. Sample test results can vary significantly depending on the ways in which a sorghum lot was loaded onto a conveyance and the method of sampling used.

IV. HARVEST 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 that 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 83 of this report.

SUMMARY: GRADE FACTORS AND MOISTURE

- *Average U.S. Harvest Aggregate test weight in 2015 was 58.9 lb/bu (75.9 kg/hl), with 84.5% of the samples at or above the factor limit for U.S. No. 1 grade and 97% of the samples at or above the limit for U.S. No. 2 grade (55.0 lb/bu or 70.8 kg/hl).*
- *Average U.S. Harvest Aggregate broken kernels and foreign material (BNFM) in the 2015 samples (1.7%) was well below the maximum for U.S. No. 1 grade (3.0%), with 99% of the samples at or below the maximum for U.S. No. 2 grade (6.0%) and 91% of the samples also at or below the maximum for U.S. No. 1 grade.*
- *Foreign material in the U.S. Harvest Aggregate samples averaged 0.6% in 2015, well below the maximum value of 1.0% for U.S. No. 1 grade. 98% of the samples were at or below the maximum foreign material allowable for U.S. No. 2 grade (2.0%).*
- *Total damage in the 2015 U.S. Harvest Aggregate samples was distributed with 99% of the samples having 2% or less damaged kernels (the maximum allowable for U.S. No. 1 grade), and 99.5% having 5% or less (the maximum allowable for U.S. No. 2 grade).*
- *There was no heat damage observed in any of the 2015 U.S. Harvest Aggregate samples.*
- *The U.S. Harvest Aggregate moisture contents recorded at the elevator in the 2015 samples averaged 14.1%, with a minimum value of 10.1% and a maximum value of 17.9%.*

IV. HARVEST QUALITY TEST RESULTS (continued)

1. Test Weight

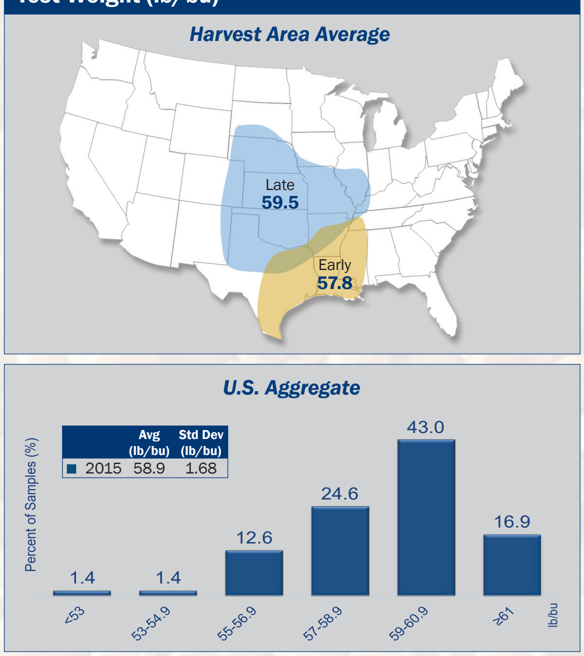
U.S. Grade Minimum Test Weight
No. 1: 57.0 lbs
No. 2: 55.0 lbs
No. 3: 53.0 lbs

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 takes 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[1].

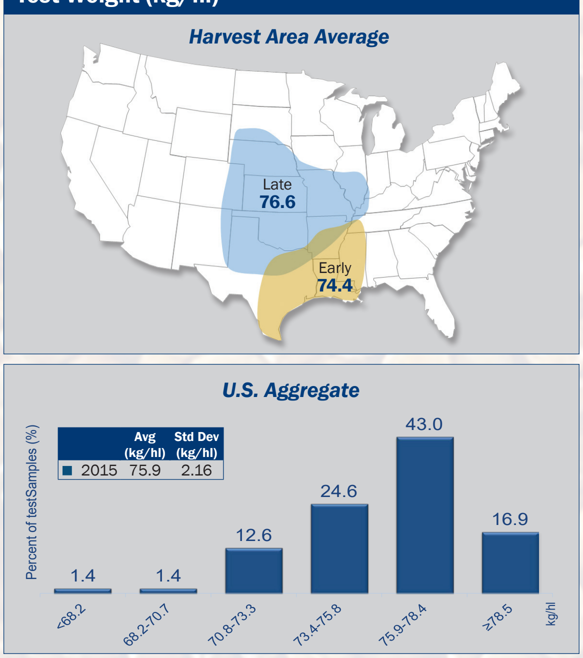
RESULTS

- Average U.S. Harvest Aggregate test weight in 2015 was 58.9 lb/bu (75.9 kg/hl), above the minimum for U.S. No. 1 grade (57.0 lb/bu or 73.4 kg/hl).
- The test weight values for the 2015 average U.S. Harvest Aggregate samples had a standard deviation of 1.68 lb/bu (2.16 kg/hl).
- The 2015 U.S. Harvest Aggregate test weight values were distributed with 84.5% of the samples at or above the factor limit for U.S. No. 1 grade and 97.1% of the samples at or above the limit for U.S. No. 2 grade (55.0 lb/bu or 70.8 kg/hl).
- Late Harvest average test weight (59.5 lb/bu or 76.6 kg/hl) in 2015 was slightly higher than Early Harvest average test weight (57.8 lb/bu or 74.4 kg/hl), which may be attributable to the more favorable weather conditions for grain fill in the Late Harvest Area compared to the Early Harvest Area.

Test Weight (lb/bu)



Test Weight (kg/hl)



[1] Buffo, R.A., C.L. Weller and A.M. Parkhurst. 1998. Relationship among grain sorghum quality factors. Cereal Chemistry 75(1):100-104.

2. Broken Kernels and Foreign Material (BNFM)

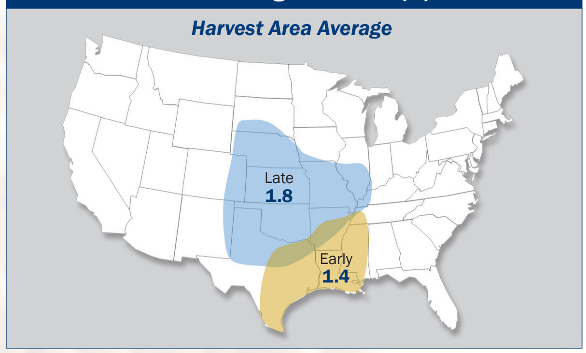
Broken kernels and foreign material (BNFM) is an indicator of the amount of clean, sound sorghum available for feed and processing. The lower the percentage of BNFM, the less foreign material and/or fewer broken kernels are in a sample. Higher levels of BNFM in farm-originated samples generally stem 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.

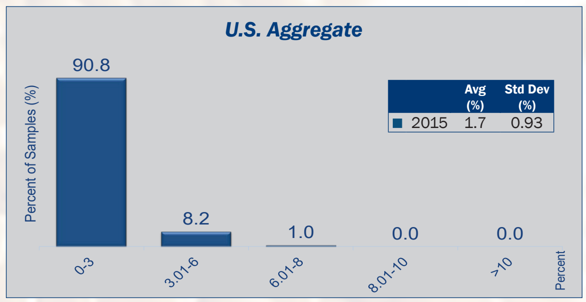
U.S. Grade BNFM Maximum Limits
No. 1: 3.0%
No. 2: 6.0%
No. 3: 8.0%

RESULTS

- U.S. Harvest Aggregate average BNFM in the 2015 samples (1.7%) was well below the maximum for U.S. No. 1 grade (3.0%).
- The BNFM values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.93%.
- Of the 2015 U.S. Harvest Aggregate samples, 99% were at or below the maximum for U.S. No. 2 grade (6.0%), with 90.8% of the samples also at or below the maximum for U.S. No. 1 grade.
- The 2015 sorghum crop condition rated higher than the average of the previous five crop years throughout most of the growing season. These high crop ratings were reflected in the U.S. Harvest Aggregate BNFM values all being at or below the maximum for U.S. No. 2 grade (6%). In addition, 92% of the samples were at or below the maximum for U.S. No. 1 grade (3%).

Broken Kernel and Foreign Material (%)





3. Foreign Material

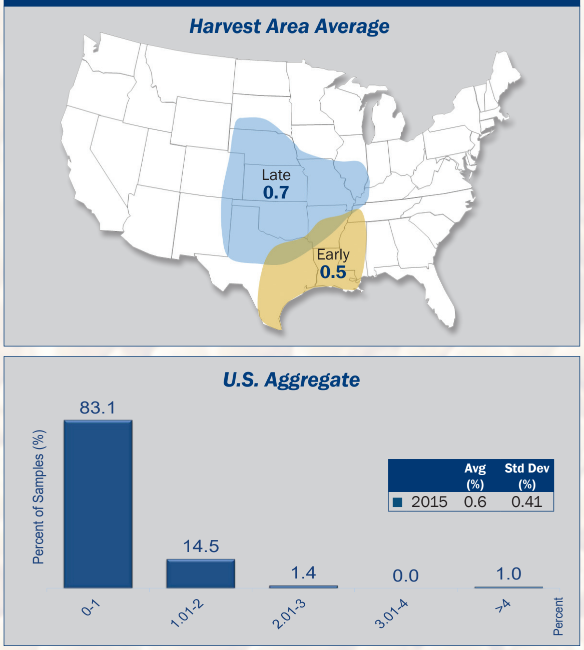
Foreign material, a subset of BNFM, is of importance because it has little feed or processing value. It is also generally higher in moisture content than the sorghum itself, and therefore creates a potential for deterioration of sorghum quality during storage. Foreign material also contributes to the spout-line 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 U.S. Harvest Aggregate samples averaged 0.6% in 2015, well below the maximum value of 1.0% for U.S. No. 1 grade.
- The foreign material values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.41%.
- In the 2015 U.S. Harvest Aggregate samples, 97.6% were at or below the maximum foreign material allowable for U.S. No. 2 grade (2.0%).
- Late Harvest average foreign material (0.7%) in 2015 was slightly higher than Early Harvest average foreign material (0.5%), which may be attributable to pest pressure differences in the growing areas of the samples.

Foreign Material (%)



4. Total Damage

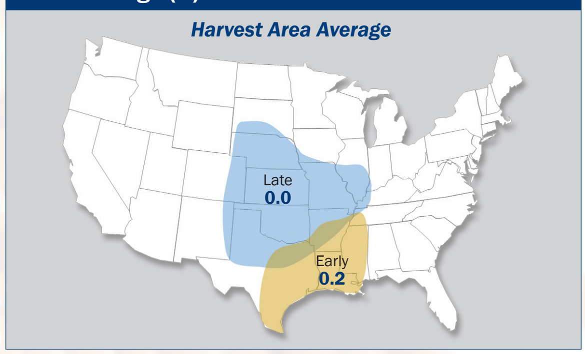
U.S. Grade Total Damage Maximum Limits
No. 1: 2.0%
No. 2: 5.0%
No. 3: 10.0%

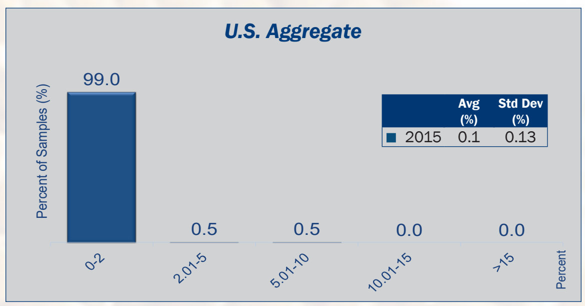
Total damage is the percentage of kernels and pieces of kernels that are visually damaged in some way, including badly ground-damaged, badly weather-damaged, diseased, frost-damaged, germ-damaged, heat-damaged, insect-bored, mold-damaged, sprout-damaged, or otherwise materially damaged. Most of these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

- Average U.S. Harvest Aggregate total damage was 0.1% in 2015, well below the limit for U.S. No. 1 grade (2%).
- The total damage values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.13%.
- Total damage in the 2015 U.S. Harvest Aggregate samples was distributed with 99% of the samples having 2% or less damaged kernels (the maximum allowable for U.S. No. 1 grade), and 99.5% having 5% or less (the maximum allowable for U.S. No. 2 grade).
- No damage was observed in Late Harvest samples, whereas the observed levels for Aggregate samples can be attributed to the damage observed in Early Harvest samples. The absence of damage in the Late Harvest samples may have been due to lack of weather and pest problems, along with good harvesting conditions and rapid transit to the elevator.

Total Damage (%)





5. Heat Damage

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

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

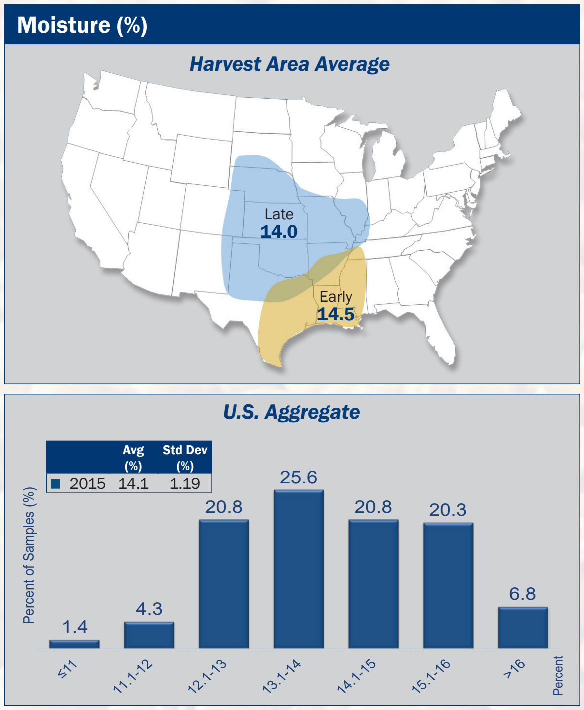
- There was no heat damage observed in any of the 2015 U.S. Harvest Aggregate samples.
- The absence of heat damage likely was due in part to recently-harvested samples coming directly from farm to elevator with minimal prior drying.

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. Also an indicator for potential drying, moisture 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 U.S. Harvest Aggregate moisture contents recorded at the elevator in the 2015 samples averaged 14.1%, with a minimum value of 10.1% and a maximum value of 17.9%.
- The moisture content values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 1.19%.
- The 2015 U.S. Harvest Aggregate moisture values were distributed with only 52.1% of the samples containing 14% or less moisture. The 14% moisture level 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.
- Late Harvest average moisture content (14.0%) in 2015 was slightly lower than Early Harvest average moisture content (14.5%). The difference may have been attributable to greater in-field dry down for Late Harvest samples than Early Harvest samples due to a longer harvest window and more favorable weather conditions during harvest.



SUMMARY: GRADE FACTORS AND MOISTURE

	2015 Harvest				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Harvest Aggregate					
Test Weight (lb/bu)	207	58.9	1.68	46.1	62.5
Test Weight (kg/hl)	207	75.9	2.16	59.3	80.4
BNFM (%)	207	1.7	0.93	0.0	6.7
Foreign Material (%)	207	0.6	0.41	0.0	4.8
Total Damage (%)	207	0.1	0.13	0.0	5.7
Heat Damage (%)	207	0.0	0.00	0.0	0.0
Moisture (%)	207	14.1	1.19	10.1	17.9
Early					
Test Weight (lb/bu)	50	57.8	2.20	46.1	62.0
Test Weight (kg/hl)	50	74.4	2.83	59.3	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	0.86	11.7	17.3
Late					
Test Weight (lb/bu)	157	59.5	1.42	53.9	62.5
Test Weight (kg/hl)	157	76.6	1.83	69.4	80.4
BNFM (%)	157	1.8	1.08	0.0	6.7
Foreign Material (%)	157	0.7	0.47	0.0	4.8
Total Damage (%)	157	0.0	0.00	0.0	0.0
Heat Damage (%)	157	0.0	0.00	0.0	0.0
Moisture (%)	157	14.0	1.36	10.1	17.9

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, U.S. Harvest Aggregate protein concentration averaged 10.9%, with a range from 6.8 to 14.1%.*
- *Protein concentration in the 2015 U.S. Harvest Aggregate samples was distributed with only 9% of samples below 9.0%, 41% between 9.0 and 10.99%, and 51% at or above 11.0%.*
- *U.S. Harvest Aggregate starch concentration averaged 73.2% in 2015, with a range from 68.7 to 75.6%.*
- *Starch concentration in the 2015 U.S. Harvest Aggregate samples was distributed with 34% of samples between 70.00 and 72.99%, 46% between 73.00 and 73.99%, and 20% equal to or greater than 74.00%.*
- *U.S. Harvest Aggregate oil concentration averaged 4.5% in 2015, with a range from 3.0 to 5.1%.*
- *Almost two-thirds of 2015 U.S. Harvest Aggregate samples (66%) had an oil concentration at 4.50% and higher, with 20% of samples at 4.00 to 4.49% and 14% at 3.99% or lower.*
- *All 2015 U.S. Harvest Aggregate samples were considered tannin-free.*

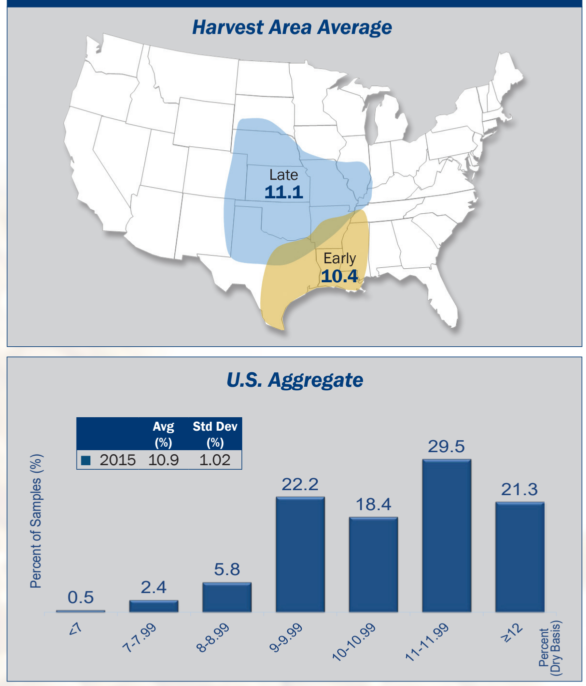
1. Protein

Protein is very important for poultry and livestock feeding, as 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, U.S. Harvest Aggregate protein concentration averaged 10.9%, which is in the range of typical protein concentration values in literature for U.S. sorghum hybrids.
- The protein concentration values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 1.02%.
- Protein concentration range for the U.S. Harvest Aggregate samples was from 6.8 to 14.1% in 2015.
- Protein concentration in the 2015 U.S. Harvest Aggregate samples was distributed with only 8.7% of samples below 9.00%, 40.6% between 9.00 and 10.99%, and 50.8% at or above 11.00%.
- Late Harvest samples had an average protein concentration of 11.1, whereas the Early Harvest samples had an average protein concentration of 10.4%.

Protein (Dry Basis %)

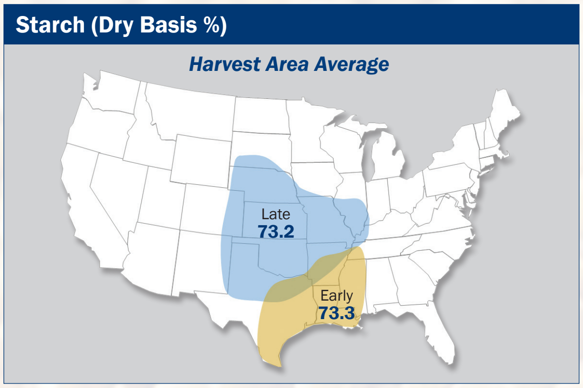


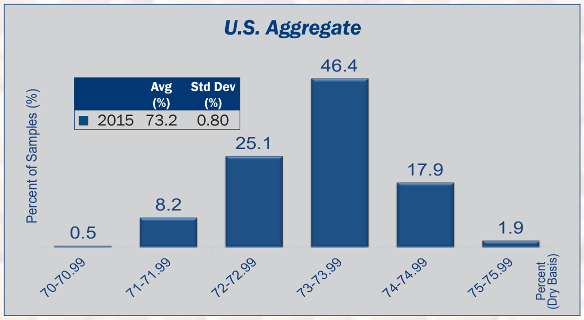
2. Starch

Starch is an important factor for sorghum and is 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

- U.S. Harvest Aggregate starch concentration averaged 73.2% in 2015, a typical level for any commercial hybrid sorghum sample.
- The starch concentration values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.80%.
- Starch concentration range for the U.S. Harvest Aggregate samples was from 68.7 to 75.6% in 2015.
- Starch concentration in the 2015 U.S. Harvest Aggregate samples was distributed with 33.8% of samples between 70.00 and 72.99%, 46.4% between 73.00 and 73.99%, and 19.8% equal to or greater than 74.00%.
- Average starch concentration for Late Harvest samples (73.2%) was essentially the same as that for Early Harvest samples (73.3%), but the range in Late Harvest starch values (68.7 to 75.6%) was greater than the range in Early Harvest samples (71.1 to 75.0%). The larger geographical area in which Late Harvest hybrids were grown likely contributed to the larger range of values in starch concentration.





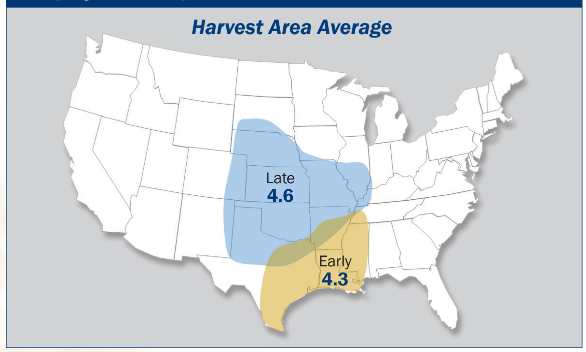
3. Oil

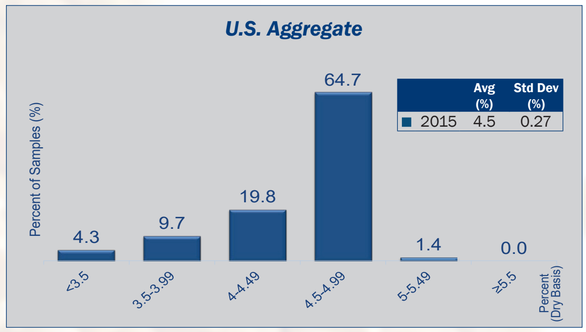
Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilized, and provides certain essential fatty acids. Oil may also be an important co-product of sorghum value-added processing. Results are reported on a dry basis.

RESULTS

- U.S. Harvest Aggregate oil concentration averaged 4.5% in 2015, which is in the normal range of typical oil concentration values in literature for U.S. sorghum hybrids.
- The oil concentration values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.27%.
- Oil concentration range for the U.S. Harvest Aggregate samples was from 3.0 to 5.1% in 2015.
- Almost two-thirds of 2015 U.S. Harvest Aggregate samples (66.1%) had an oil concentration at 4.50% and higher, with 19.8% of samples at 4.00 to 4.49%, and 14% at 3.99% or lower.
- Late Harvest samples had an average oil concentration of 4.6%, whereas the Early Harvest samples had an average oil concentration of 4.3%.

Oil (Dry Basis %)





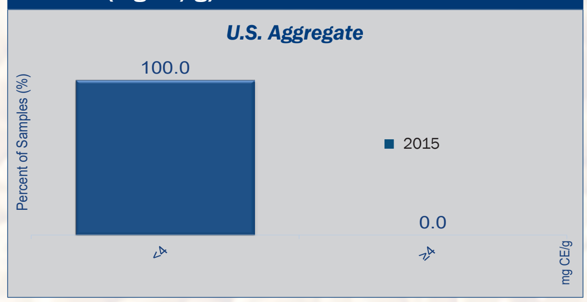
4. Tannins

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 phenolic molecules (catechins, epicatechins, etc.) and are widely distributed in nature (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 nutrients in the kernel. Livestock and poultry growth performance can be negatively affected by the 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 (4.0 mg CE/g) or above. Values below 4.0 mg CE/g generally imply absence of condensed tannins[2, 3].

RESULTS

- All observed tannin levels in the 2015 U.S. Harvest Aggregate samples (includes all Late and Early Harvest samples) were less than 4.0 mg CE/g, implying an absence of tannins.

Tannins (mg CE/g)



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

[3] *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.*

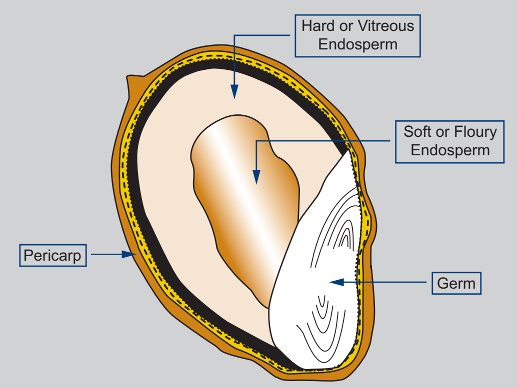
SUMMARY: CHEMICAL COMPOSITION

	2015 Harvest				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Harvest Aggregate					
Protein (Dry Basis %)	207	10.9	1.02	6.8	14.1
Starch (Dry Basis %)	207	73.2	0.80	68.7	75.6
Oil (Dry Basis %)	207	4.5	0.27	3.0	5.1
Early					
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
Late					
Protein (Dry Basis %)	157	11.1	1.15	6.8	14.1
Starch (Dry Basis %)	157	73.2	0.86	68.7	75.6
Oil (Dry Basis %)	157	4.6	0.25	3.3	5.1

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.

Sorghum Kernel



Adapted from Rooney and Miller, 1982

SUMMARY: PHYSICAL FACTORS

- *For the U.S. Harvest Aggregate sorghum samples in 2015, kernel diameter averaged 2.53 mm, TKW averaged 26.30 g, and kernel volume averaged 19.34 mm^3.*
- *U.S. Harvest Aggregate kernel true density averaged 1.359 g/cm^3 in 2015, with a range from 1.295 to 1.402 g/cm^3 and 88% of samples between 1.345 g/cm^3 and 1.389 g/cm^3.*
- *On average, the U.S. Harvest Aggregate samples had less volume than typical for U.S. sorghum hybrids, but kernel diameter, weight, and true density were within the range of values reported in literature for commercial sorghum hybrids.*
- *Kernel hardness index averaged 71.0 for U.S. Harvest Aggregate samples in 2015, with a range from 37.1 to 91.5 and 90% of samples between 40.00 and 79.99.*

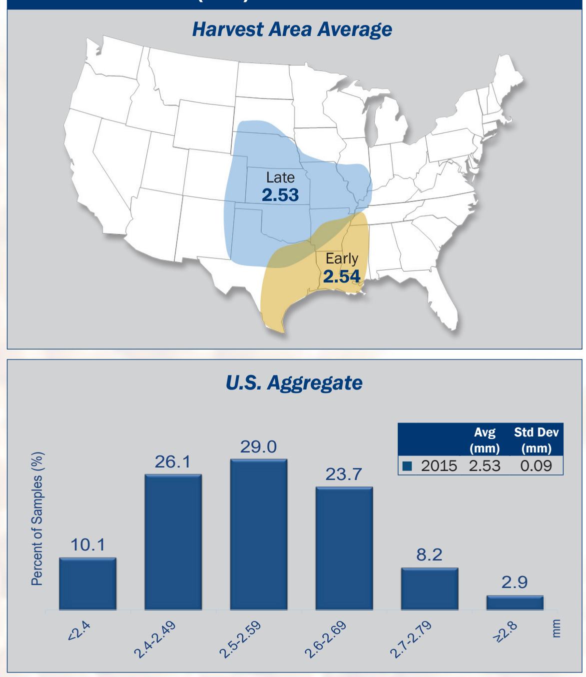
1. Kernel Diameter

Kernel diameter (reported in mm) 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

- U.S. Harvest Aggregate kernel diameter averaged 2.53 mm in 2015, a typical value for any commercial sorghum hybrid sample.
- The kernel diameter values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.09 mm.
- Kernel diameters for the U.S. Harvest Aggregate samples ranged from 2.18 to 2.90 mm in 2015.
- In 2015, U.S. Harvest Aggregate kernel diameters were distributed so that 11.1% of the samples had kernel diameters of 2.70 mm or greater, 52.7% were between 2.50 and 2.69 mm, and 36.2% were less than 2.50 mm.

Kernel Diameter (mm)



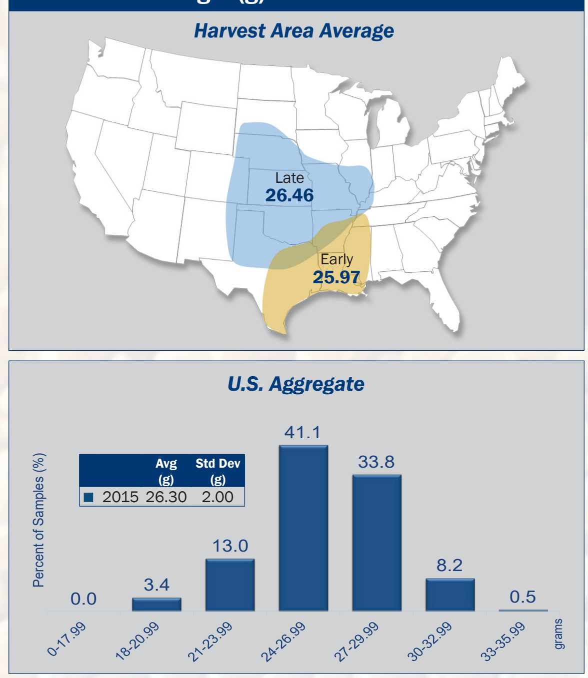
2. 1000-Kernel Weight (TKW)

1000-kernel weight (commonly referred to as TKW) is the weight for a fixed number of kernels, and is reported in grams. Kernel volume (or size) can be inferred from TKW, since as TKW 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

- TKW averaged 26.30 g for U.S. Harvest Aggregate samples in 2015, a value within the range of typical TKW values in literature for U.S. sorghum hybrids.
- The TKW values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 2.00 g.
- TKW for the U.S. Harvest Aggregate samples ranged from 19.49 to 34.66 g in 2015.
- In the 2015 U.S. Harvest Aggregate samples, TKWs were distributed so that 8.7% of the samples had TKW of 30.00 g or greater, 74.9% had between 24.00 and 29.99 g, and 16.4% less than 24.00 g.
- The slightly greater average TKW for Late Harvest samples (26.46 g) than the average TKW for Early Harvest samples (25.97 g) generally parallels the trend observed for respective sample test weight averages.

1000-Kernel Weight (g)



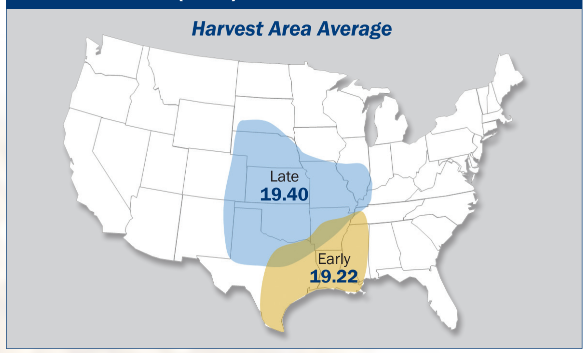
3. Kernel Volume

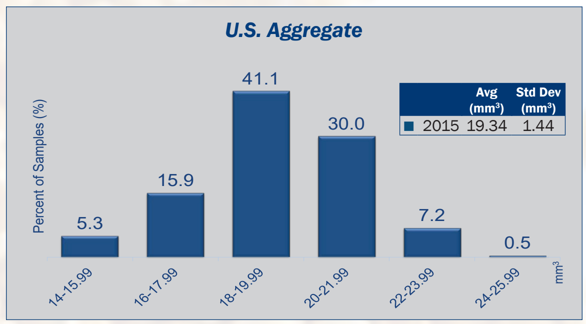
Kernel volume (or size), reported in mm^3, is directly related to kernel diameter and is often indicative of growing conditions. If conditions are dry, kernels may be small due to stunted development. If drought hits later in the season, kernels may have lower fill. Small kernels are more difficult to 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

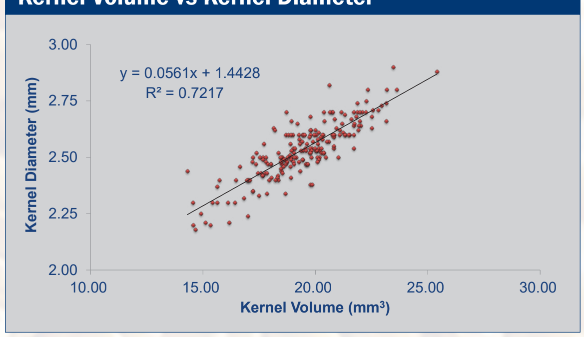
- Kernel volume averaged 19.34 mm^3 for U.S. Harvest Aggregate samples in 2015, a value on the lower end of typical volume values in literature for any commercial sorghum hybrid sample.
- The kernel volume values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 1.44 mm^3.
- Kernel volumes for the U.S. Harvest Aggregate samples ranged from 14.31 to 25.40 mm^3 in 2015.
- In the 2015 U.S. Harvest Aggregate samples, kernel volumes were distributed so that 21.2% of the samples had kernel volumes of less than 18.00 mm^3, 71.1% were between 18.00 and 21.99 mm^3, and 7.9% were equal to or greater than 22.00 mm^3.
- The kernel volume average for Late Harvest samples (19.40 mm^3) was slightly higher than the average for Early Harvest samples (19.22 mm^3).
- Kernel volume had a positive relationship (a correlation coefficient of 0.85) with kernel diameter for the 2015 U.S. Harvest Aggregate samples, as shown in the adjacent figure.

Kernel Volume (mm^3)





Kernel Volume vs Kernel Diameter



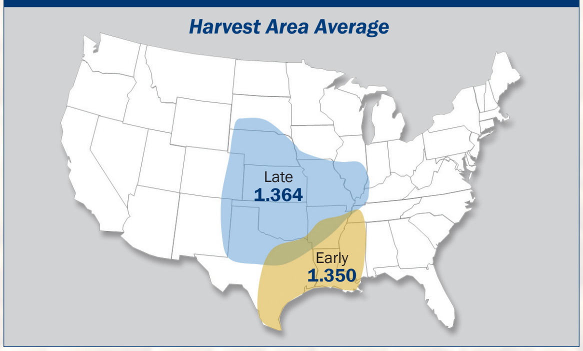
4. Kernel True Density

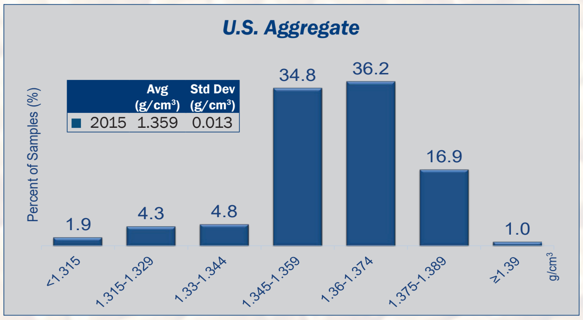
Kernel true density (kernel weight per kernel volume, reported as g/cm^3) is a relative indicator of kernel hardness, which is useful during size reduction operations. Genetics of the sorghum hybrid and the growing environment affect kernel true density. Sorghum with higher density is typically less susceptible to breakage in handling than lower-density sorghum. Most sorghum used for feed 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

- U.S. Harvest Aggregate kernel true density averaged 1.359 g/cm^3 in 2015, which falls within the range of values in literature for U.S. sorghum hybrids.
- The true density values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 0.013 g/cm^3.
- True densities for the 2015 U.S. Harvest Aggregate samples ranged from 1.295 to 1.402 g/cm^3.
- In the 2015 U.S. Harvest Aggregate samples, kernel true densities were distributed so that 1.9% of the samples were below 1.315 g/cm^3, 4.3% between 1.315 and 1.329 g/cm^3, 4.8% between 1.330 and 1.344 g/cm^3, and 88.9% between 1.345 g/cm^3 and above.
- The slightly greater average true densities for Late Harvest samples (1.364 g/cm^3) than the average true densities for Early Harvest samples (1.350 g/cm^3) generally parallels the trend observed for respective sample test weight averages.

True Density (g/cm^3)





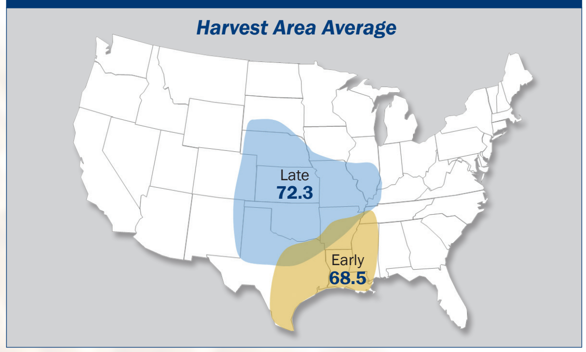
5. Kernel Hardness Index

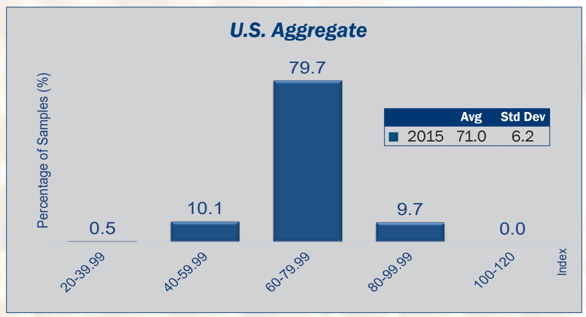
Kernel hardness affects resistance to molds and insects, size reduction behavior, and the end use of sorghum. Sieving behavior, size reduction energy consumption, particle size distribution of ground material, and yield of kernel components depend on hardness. Harder sorghum not only produces coarser or larger particles than softer sorghum; it also requires more energy per mass of sorghum to achieve similar particle size distribution during size reduction. As a result, 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

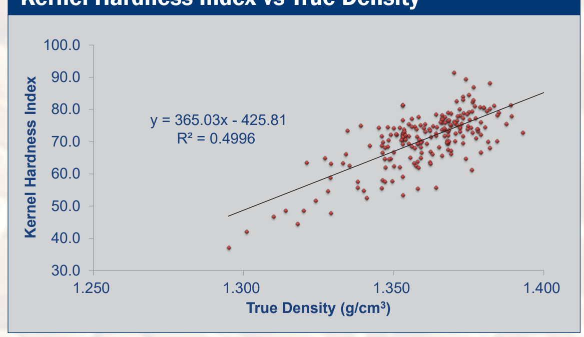
- Kernel hardness index averaged 71.0 for U.S. Harvest Aggregate samples in 2015, a typical value for any commercial sorghum hybrid sample.
- The kernel hardness index values for the 2015 U.S. Harvest Aggregate samples had a standard deviation of 6.2.
- Kernel hardness index for the U.S. Harvest Aggregate samples ranged from 37.1 to 91.5 in 2015.
- In the 2015 U.S. Harvest Aggregate samples, kernel hardness indices were distributed so that 9.7% of the samples had kernel hardness indices of 80.00 or greater, 89.8% had 40.00 to 79.99, and 0.5% had less than 40.00.
- The slightly greater average kernel hardness index for Late Harvest samples (72.3) than the average kernel hardness index for Early Harvest samples (68.5) generally parallels the trend observed for respective sample test weight averages.
- Kernel hardness had a weak but positive relationship with true density (a correlation coefficient of 0.71), as shown in the adjacent figure.

Kernel Hardness Index





Kernel Hardness Index vs True Density



SUMMARY: PHYSICAL FACTORS

	2015 Harvest				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Harvest Aggregate					
Kernel Diameter (mm)	207	2.53	0.09	2.18	2.90
TKW (g)	207	26.30	2.00	19.49	34.66
Kernel Volume (mm^3)	207	19.34	1.44	14.31	25.40
True Density (g/cm^3)	207	1.359	0.013	1.295	1.402
Kernel Hardness Index	207	71.0	6.2	37.1	91.5
Early					
Kernel Diameter (mm)	50	2.54	0.10	2.20	2.90
TKW (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
Late					
Kernel Diameter (mm)	157	2.53	0.09	2.18	2.88
TKW (g)	157	26.46	1.84	19.49	34.66
Kernel Volume (mm^3)	157	19.40	1.36	14.31	25.40
True Density (g/cm^3)	157	1.364	0.012	1.327	1.402
Kernel Hardness Index	157	72.3	5.9	47.9	91.5

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 sorghum and other grains, aflatoxins and deoxynivalenol (DON or vomitoxin) are considered to be two of the important mycotoxins.

The 2015 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 Survey* is strictly to report on instances when aflatoxins or DON are detected in the sorghum crop at harvest. No specific levels of the mycotoxins are reported.

The *Harvest Survey* review of mycotoxins is NOT intended to predict the presence or level at which mycotoxins might appear in U.S. sorghum 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 sorghum exports are less than what might first appear in the sorghum 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 all of the top sorghum-producing states surveyed. The *Harvest Survey's* results should be used only as one indicator of the potential for mycotoxin presence in the sorghum as the crop comes out of the field. As the Council accumulates several years of the *Sorghum Harvest & Export Cargo Reports*, year-to-year patterns of mycotoxin presence in sorghum at harvest will be seen. The "Export Quality Test Results" section will report sorghum quality at export points and will be a more accurate indication of mycotoxin presence in the 2015/2016 U.S. sorghum export shipments.

ASSESSING THE PRESENCE OF AFLATOXINS AND DON

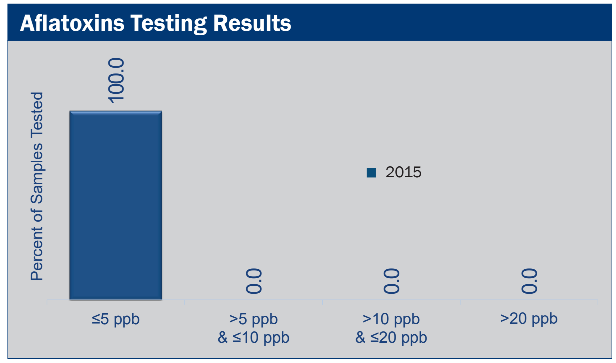
A weighted and systematic testing of at least 25% of the targeted 200 samples across the entire sampled area was conducted to assess the impact of the 2015 growing conditions on total aflatoxins and DON development in the U.S. sorghum crop. The sampling criteria, described in the "Survey and Statistical Analysis Methods" section, resulted in a targeted number of 58 samples tested for mycotoxins.

A threshold established by 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 analytical kits approved by FGIS and used for this 2015/2016 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 2.0 ppb and 0.1 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 58 harvest samples were analyzed for aflatoxins in 2015. Results of the 2015 *Harvest Survey* are as follows:

- All fifty-eight (58) samples, or 100% of the 58 survey samples, had no detectable levels of aflatoxins (sample test results were less than or equal to the FGIS LCL of 5.0 ppb).
- No samples (0), or 0.0% of the 58 samples, showed aflatoxin levels greater than the LCL of 5.0 ppb, but less than or equal to 10 ppb.
- No samples (0), or 0.0% of the 58 samples, showed aflatoxin levels greater than 10 ppb, but less than or equal to the Food and Drug Administration (FDA) action level of 20 ppb.

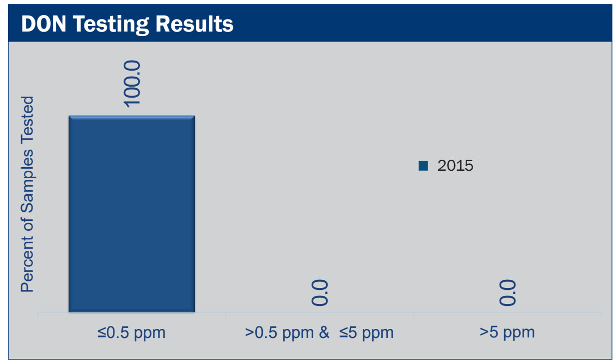


- No samples (0), or 0.0%, of the 58 samples, showed aflatoxin levels greater than the FDA action level of 20 ppb.

All survey samples from the 2015 crop season tested below the FGIS LCL value of 5.0 ppb, indicating that the contamination level in the domestic crop was potentially minimal. This may have been due, in part, to favorable weather conditions in 2015 (see the "Crop and Weather Conditions" section for more information on the 2015 growing conditions). Weather was cool and wet in 2015 and as a result, the plants were not under stress. These conditions were not conducive to aflatoxin formation.

RESULTS: DON (DEOXYNIVALENOL OR VOMITOXIN)

A total of 58 samples was analyzed collectively for DON in 2015. Results of the 2015 survey are shown below:



- All fifty-eight (58) samples, or 100.0% of the 58 survey samples, had no detectable levels of DON (all samples tested less than or equal to the FGIS LCL of 0.5 ppm).
- No samples (0), or 0.0% of the 58 samples, tested greater than 0.5 ppm, but less than or equal to the FDA advisory level of 5 ppm.
- No samples (0), or 0.0% of the 58 samples, tested greater than the FDA advisory level of 5 ppm.
- In 2015, all 58 samples, or 100%, tested below the FDA advisory level of 5 ppm.

In 2015, all 58 samples, or 100%, tested below the FDA advisory limit of 5 ppm. In fact, all survey samples tested below the FGIS LCL threshold of 0.5 ppm, indicating that the DON contamination level in the domestic crop was potentially minimal. The fact that all survey samples tested below the FGIS LCL threshold of 0.5 ppm may be due, in part, to weather conditions less conducive to DON development in 2015 (see the "Crop and Weather Conditions" section for more information on the 2015 growing conditions).

1. Background: General

The levels at which the fungi produce the mycotoxins are impacted by the fungus type and the environmental conditions under which the sorghum is produced and stored. Because of these differences, mycotoxin production varies across the U.S. sorghum-producing areas and across years. In some years, the growing conditions across the sorghum-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 sorghum's use for human and livestock consumption. Humans and livestock are sensitive to mycotoxins at varying levels. As a result, the 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 import 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", which can be found at *http://www.ngfa.org/wp-content/uploads/NGFAComplianceGuide-FDARegulatoryGuidanceforMycotoxins8-2011.pdf*.

2. Background: Aflatoxins

The most important type of mycotoxin associated with sorghum 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 plant and often penetrates kernels through wounds produced by insects.

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 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 in poultry and ducks, 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 due to aflatoxin ingestion.

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 grains with levels of aflatoxins exceeding these threshold levels. In general, the FDA currently does not permit the blending of grains containing aflatoxin with uncontaminated grain to reduce the aflatoxin content of the resulting mixture to levels acceptable for use as human food or animal feed.

If required by the buyer, sorghum exported from the United States will be tested for aflatoxins by FGIS. Sorghum above the FDA action level of 20 ppb or the buyer’s specification cannot be exported unless other strict conditions are met. These requirements result 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

3. Background: DON (Deoxynivalenol or Vomitoxin)

DON is another mycotoxin of concern to some importers of sorghum grain. It is produced by certain species of *Fusarium*, the most important of which is *Fusarium graminearum* (*Gibberellazeae*). *Gibberellazeae* can develop when cool or moderate and wet weather occurs at flowering. Mycotoxin contamination of sorghum caused by *Gibberellazeae* is often associated with excessive postponement of harvest and/or storage of high-moisture sorghum.

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 sorghum and may have low weight gain, diarrhea, lethargy, and intestinal hemorrhaging. Additionally, DON 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 grain products, 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 sorghum bound for export markets, but will perform either a qualitative or quantitative test for DON at the buyer’s request.

V. EXPORT 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 that 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 83 of this report. For this *2015/2016 Export Survey*, all of the export samples received were from sublots with contracts that were specified as grade U.S. No. 2 or better, which is the most common grade for which U.S. sorghum export contracts are written.

SUMMARY: GRADE FACTORS AND MOISTURE

- *Average U.S. Export Aggregate test weight in 2015/2016 was 59.0 lb/bu (76.0 kg/hl), above the minimum for U.S. No. 1 grade sorghum (57.0 lb/bu or 73.4 kg/hl), with 100% of the samples at or above the limit for U.S. No. 2 grade (55.0 lb/bu or 70.8 kg/hl).*
- *Average U.S. Export Aggregate broken kernels and foreign material (BNFM) in the 2015/2016 samples (1.9%) was well below the maximum for U.S. No. 1 grade (3.0%), with all samples at or below the maximum for U.S. No. 2 grade (6.0%).*
- *Average foreign material in the 2015/2016 U.S. Export Aggregate samples (0.9%) was below the maximum for U.S. No. 1 grade (1.0%), with 98.3% of the samples at or below the maximum foreign material allowable for U.S. No. 2 grade (2.0%).*
- *Total damage average for the 2015/2016 U.S. Export Aggregate samples (0.5%) was well below the maximum for U.S. No. 1 grade (2.0%), with 100% of the samples having 5.0% or less (the maximum allowable for U.S. No. 2 grade).*
- *Average test weight for the NOLA EO (59.3 lb/bu or 76.4 kg/hl) was higher than for the Texas EO (57.8 lb/bu or 74.5 kg/hl).*
- *Average foreign material and total damage for the NOLA EO (0.8% and 0.4%, respectively) were lower than for the Texas EO (1.0% and 0.8%).*
- *No difference was observed in average BNFM between the NOLA (1.9%) and Texas (1.9%) EOs.*
- *There was no heat damage observed in any of the 2015/2016 U.S. Export Aggregate samples.*
- *Average U.S. Aggregate values for BNFM, foreign material, and total damage were all higher at export than at harvest, which was expected. However, the standard deviations for these tests all indicated more uniformity at export than at harvest.*
- *Average U.S. Export Aggregate moisture content was 13.8%. Average moisture content was slightly higher for the NOLA EO (13.8%), with more variability than for the Texas EO (13.6%).*
- *Average U.S. Aggregate moisture was lower at export than at harvest (14.1%); the standard deviation of export samples indicated much more uniformity of moisture at export than at harvest.*

1. Test Weight

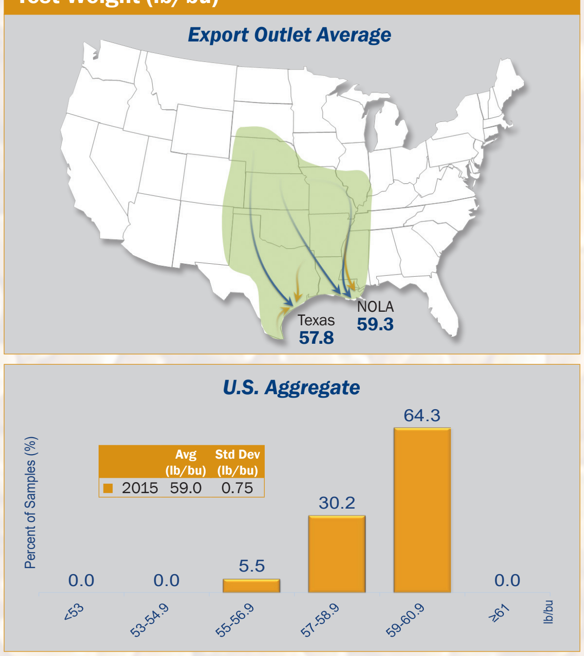
U.S. Grade Minimum Test Weight
No. 1: 57.0 lbs
No. 2: 55.0 lbs
No. 3: 53.0 lbs

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 takes 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[1].

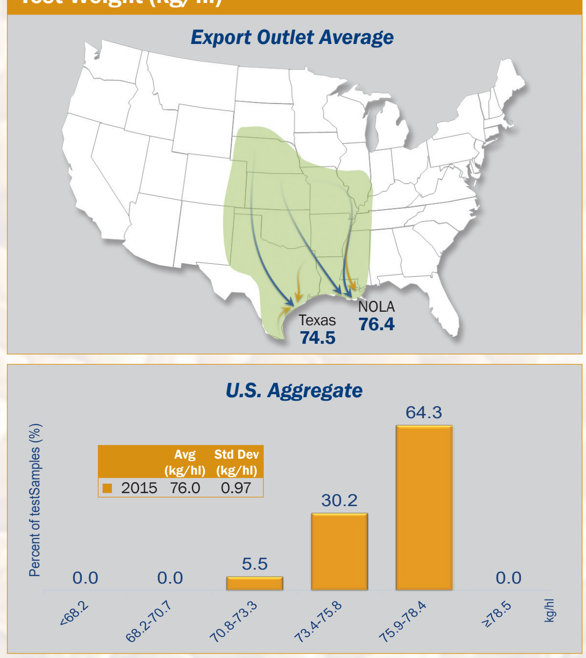
RESULTS

- Average U.S. Export Aggregate test weight in 2015/2016 was 59.0 lb/bu (76.0 kg/hl), above the minimum for U.S. No. 1 grade (57.0 lb/bu or 73.4 kg/hl).
- The test weight values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.75 lb/bu (0.97 kg/hl) and a range of 56.2 to 60.5 lb/bu (72.3 to 77.9 kg/hl).
- Average U.S. Export Aggregate test weight was very similar to average U.S. Harvest Aggregate test weight (58.9 lb/bu or 75.9 kg/hl).
- The 2015/2016 U.S. Export Aggregate test weight values were distributed with 94.5% of the samples at or above the factor limit for U.S. No. 1 grade.
- Average test weight was higher for the NOLA EO (59.3 lb/bu or 76.4 kg/hl), with less variability than for the Texas EO (57.8 lb/bu or 74.5 kg/hl).

Test Weight (lb/bu)



Test Weight (kg/hl)



[1] *Buffo, R.A., C.L. Weller and A.M. Parkhurst. 1998. Relationship among grain sorghum quality factors. Cereal Chemistry 75(1):100-104.*

V. EXPORT QUALITY TEST RESULTS (continued)

2. Broken Kernels and Foreign Material (BNFM)

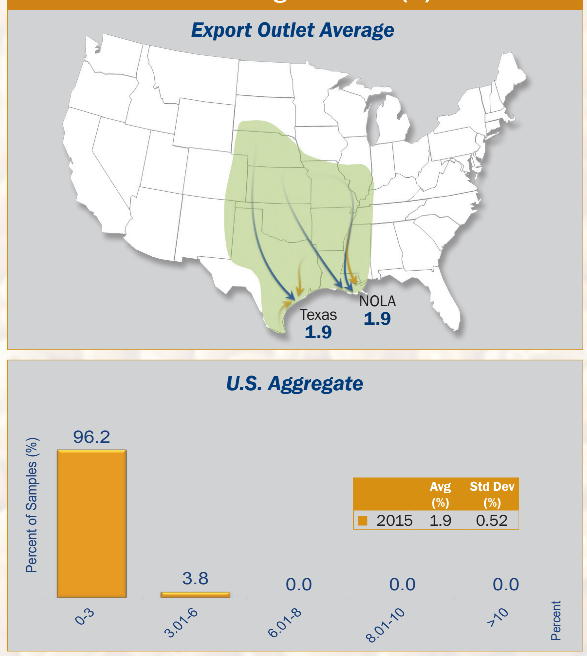
U.S. Grade BNFM Maximum Limits
No. 1: 3.0%
No. 2: 6.0%
No. 3: 8.0%

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.

RESULTS

- Average U.S. Export Aggregate BNFM in the 2015/2016 samples (1.9%) was well below the maximum for U.S. No. 1 grade (3.0%).
- The BNFM values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.52% with a range of 1.0 to 4.6%.
- Average U.S. Export Aggregate BNFM was higher than the U.S. Harvest Aggregate average (1.7%); however, the standard deviation of export samples was much lower than that for the harvest samples (0.93%).
- The 2015/2016 U.S. Export Aggregate BNFM values were all at or below the maximum for U.S. No. 2 grade (6.0%), with 96.2% of the samples also at or below the maximum for U.S. No. 1 grade (3.0%).
- No difference was observed in average BNFM between the NOLA (1.9%) and Texas (1.9%) EOs. Both averages were well below the maximum for U.S. No. 1 grade (3.0%).

Broken Kernel and Foreign Material (%)



3. Foreign Material

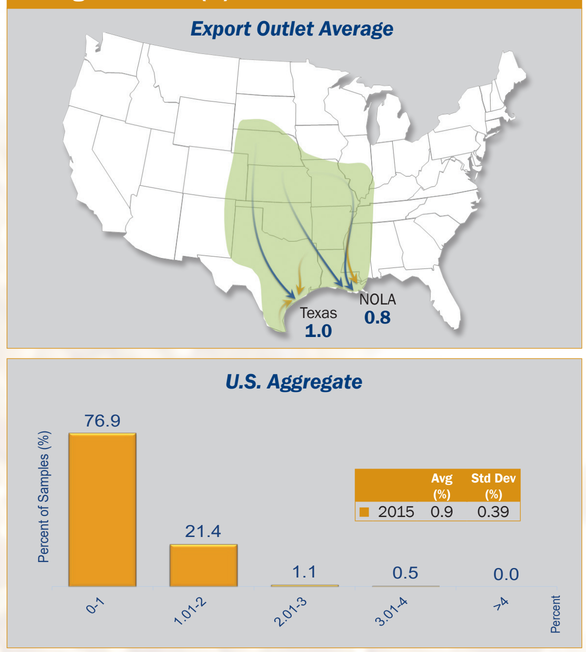
Foreign material, a subset of BNFM, is of importance because it has little feed or processing value. It is also generally higher in moisture content than the sorghum itself, and therefore creates a potential for deterioration of sorghum quality during storage. Foreign material also contributes to the spout-line 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 U.S. Export Aggregate samples averaged 0.9% in 2015/2016, below the maximum value of 1.0% for U.S. No. 1 grade.
- The foreign material values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.39% with a range of 0.1 to 3.4%.
- Average U.S. Export Aggregate foreign material was higher than the U.S. Harvest Aggregate average (0.6%); the standard deviation of export samples was slightly lower than that for the harvest samples (0.41%).
- In the 2015/2016 U.S. Export Aggregate samples, 98.3% of the samples were at or below the maximum foreign material allowable for U.S. No. 2 grade (2.0%), with 76.8% of the samples also at or below the maximum for U.S. No. 1 grade (1.0%).
- Average foreign material was slightly lower in samples for the NOLA EO (0.8%), with less variability than in samples for the Texas EO (1.0%). Both averages were at or below the maximum for U.S. No. 1 grade (1.0%).

Foreign Material (%)



V. EXPORT QUALITY TEST RESULTS (continued)

4. Total Damage

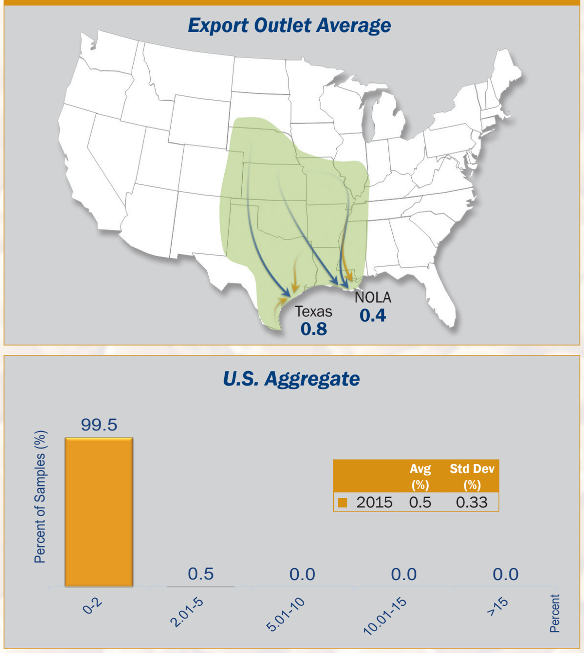
U.S. Grade Total Damage Maximum Limits
No. 1: 2.0%
No. 2: 5.0%
No. 3: 10.0%

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. 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 U.S. Export Aggregate samples averaged 0.5% in 2015/2016, well below the limit for U.S. No. 1 grade (2.0%).
- The total damage values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.33%, with a range of 0.0 to 2.1%.
- Average U.S. Export Aggregate total damage was higher than U.S. Harvest Aggregate total damage (0.1%); the standard deviation of export samples was much lower than that for the harvest samples (0.13%).
- Total damage in the 2015/2016 U.S. Export Aggregate samples was distributed with 99.5% of the samples having 2.0% or less damaged kernels (the maximum allowable for U.S. No. 1 grade), and 100% having 5.0% or less (the maximum allowable for U.S. No. 2 grade).
- Average total damage was lower for the NOLA EO (0.4%), with less variability than for the Texas EO (0.8%). Both averages were below the maximum for U.S. No. 1 grade (2.0%).

Total Damage (%)



5. Heat Damage

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

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

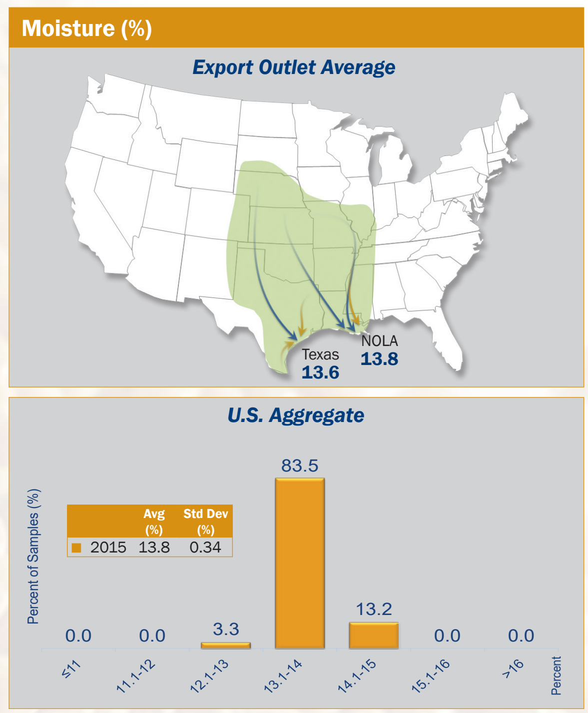
- There was no heat damage observed in any of the 2015/2016 U.S. Export Aggregate samples.
- The absence of heat damage likely was due in part to harvested samples moving quickly from farm to export loadout facility with no or minimal prior drying.

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. Also an indicator for potential drying, moisture 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 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 U.S. Export Aggregate moisture contents recorded at export loadout facilities in the 2015/2016 samples averaged 13.8%, with a minimum value of 12.3% and a maximum value of 14.6%.
- The moisture content values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.34%.
- Average U.S. Export Aggregate moisture was lower than average U.S. Harvest Aggregate moisture (14.1%); however, the standard deviation of export samples was much lower than that for the harvest samples (1.19%).
- The 2015/2016 moisture values were distributed with 86.8% of the samples containing 14% or less moisture and the other 13.2% of the samples between 14% and 15% moisture. The 14% moisture level is the base moisture used by most elevators for discounts and a level considered safe for storage for short periods during low winter-time temperatures.



- Average moisture content was slightly higher in samples for the NOLA EO (13.8%), with more variability than in samples for the Texas EO (13.6%).

V. EXPORT QUALITY TEST RESULTS (continued)

SUMMARY: GRADE FACTORS AND MOISTURE

	2015/2016 Export Cargo				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Export Aggregate					
Test Weight (lb/bu)	182	59.0	0.75	56.2	60.5
Test Weight (kg/hl)	182	76.0	0.97	72.3	77.9
BNFM (%)	182	1.9**	0.52	1.0	4.6
Foreign Material (%)	182	0.9**	0.39	0.1	3.4
Total Damage (%)	182	0.5**	0.33	0.0	2.1
Heat Damage (%)	182	0.0	0.00	0.0	0.0
Moisture (%)	182	13.8**	0.34	12.3	14.6
NOLA					
Test Weight (lb/bu)	46	59.3	0.73	56.2	59.2
Test Weight (kg/hl)	46	76.4	0.94	72.3	76.2
BNFM (%)	46	1.9	0.47	1.0	4.6
Foreign Material (%)	46	0.8	0.35	0.3	3.4
Total Damage (%)	46	0.4	0.29	0.0	2.1
Heat Damage (%)	46	0.0	0.00	0.0	0.0
Moisture (%)	46	13.8	0.36	13.1	14.1
Texas					
Test Weight (lb/bu)	136	57.8	0.82	56.7	60.5
Test Weight (kg/hl)	136	74.5	1.06	73.0	77.9
BNFM (%)	136	1.9	0.69	1.1	3.7
Foreign Material (%)	136	1.0	0.53	0.1	2.4
Total Damage (%)	136	0.8	0.48	0.0	1.3
Heat Damage (%)	136	0.0	0.00	0.0	0.0
Moisture (%)	136	13.6	0.26	12.3	14.6

*** Indicates that the 2015 Export Cargo averages were significantly different from 2015 Harvest averages, based on a 2-tailed t-test at the 95% level of significance.*

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 2015/2016, U.S. Export Aggregate protein concentration averaged 10.8%, which falls in the normal range of protein concentration values in literature for U.S. sorghum hybrids.*
- *U.S. Export Aggregate starch concentration averaged 73.0% in 2015/2016, a typical level for any sorghum sample.*
- *U.S. Export Aggregate oil concentration averaged 4.5% in 2015/2016, which falls in the normal range of oil concentration values in literature for U.S. sorghum hybrids.*
- *No difference was observed in average protein concentration between the NOLA (10.8%) and Texas (10.8%) EOs.*
- *Average concentrations for starch and oil for the NOLA EO (73.2% and 4.6%, respectively) were slightly higher than for the Texas EO (72.3% and 4.2%).*
- *Average U.S. Aggregate values for protein and starch were slightly lower at export than at harvest, whereas oil was unchanged. The standard deviations for all of these tests indicated more uniformity (lower standard deviations) at export than at harvest.*
- *All 2015/2016 U.S. Export Aggregate samples were considered tannin-free.*

V. EXPORT QUALITY TEST RESULTS (continued)

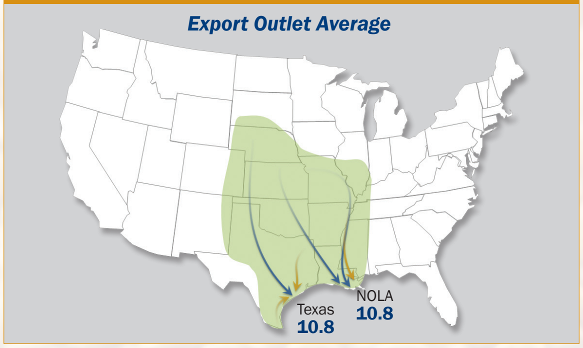
1. Protein

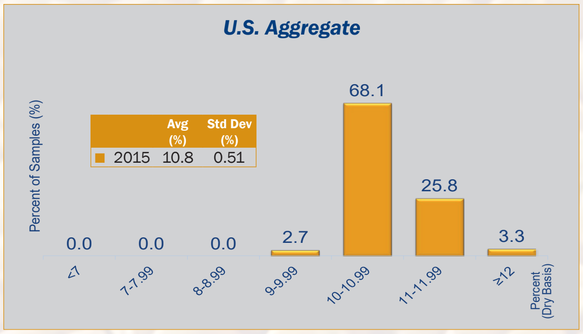
Protein is very important for poultry and livestock feeding, as it supplies essential sulfur-containing amino acids and helps to improve feed conversion efficiency. Protein is usually inversely related to starch concentration. Results are reported on a dry basis.

RESULTS

- In 2015/2016, U.S. Export Aggregate protein concentration averaged 10.8%, which falls in the normal range of protein concentration values in literature for U.S. sorghum hybrids.
- The protein concentration values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.51%.
- Protein concentration range for the U.S. Export Aggregate samples was from 9.7 to 12.6%.
- Average U.S. Export Aggregate protein was slightly lower than U.S. Harvest Aggregate samples (10.9%). The standard deviation of export samples was much lower than that for the harvest samples (1.02%).
- Protein concentration in the 2015/2016 U.S. Export Aggregate samples was distributed with 2.7% of samples below 10.00%, 93.9% between 10.00 and 11.99%, and 3.3% at or above 12.00%.

Protein (Dry Basis %)





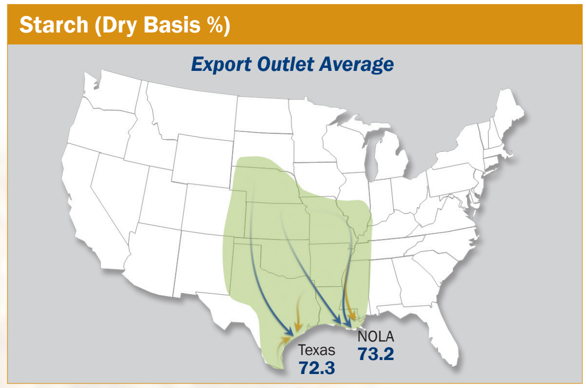
- No difference was observed in average protein concentration between the NOLA (10.8%) and the Texas (10.8%) EOs. Both averages fall in the normal range of reported protein concentration values.

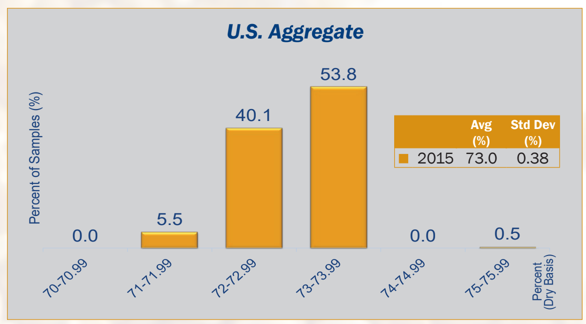
2. Starch

Starch is an important factor for sorghum and is 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

- U.S. Export Aggregate starch concentration averaged 73.0% in 2015/2016, a typical level for any sorghum samples.
- The starch concentration values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.38%.
- Starch concentration range for the U.S. Export Aggregate samples was from 71.4 to 75.0% in 2015/2016.
- Average U.S. Export Aggregate starch was slightly lower than U.S. Harvest Aggregate samples (73.2%). The standard deviation of export samples was much lower than that for the harvest samples (0.80%).
- Starch concentration in the 2015/2016 U.S. Export Aggregate samples was distributed with 5.5% of samples below 72.00%, 93.9% between 72.00 and 73.99%, and 0.5% equal to or greater than 74.00%.





- Average starch concentration was higher for the NOLA EO (73.2%), with less variability than for the Texas EO (72.3%). Both averages fall in the normal range of reported starch concentration values.

V. EXPORT QUALITY TEST RESULTS (continued)

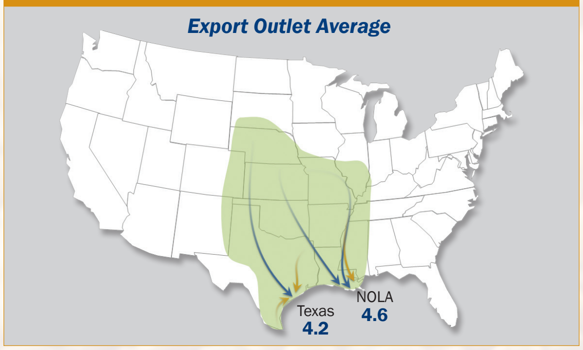
3. Oil

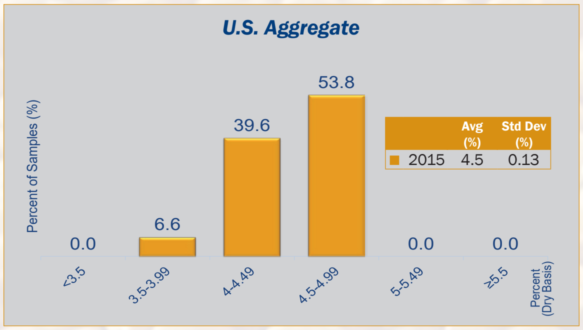
Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilized, and provides certain essential fatty acids. Oil may also be an important co-product of sorghum value-added processing. Results are reported on a dry basis.

RESULTS

- U.S. Export Aggregate oil concentration averaged 4.5% in 2015/2016, which falls in the normal range of oil concentration values in literature for U.S. sorghum hybrids.
- The oil concentration values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.13%.
- Oil concentration range for the U.S. Export Aggregate samples was from 3.7 to 4.9% in 2015/2016.
- Average U.S. Export Aggregate oil was the same as the U.S. Harvest Aggregate samples (4.5%); the standard deviation of export samples was much lower than that for the harvest samples (0.27%).
- U.S. Export Aggregate oil concentration in the 2015/2016 U.S. Export Aggregate samples was distributed with 6.6% of samples at 3.99% or lower, and 93.4% of samples at 4.00 to 4.99%.

Oil (Dry Basis %)





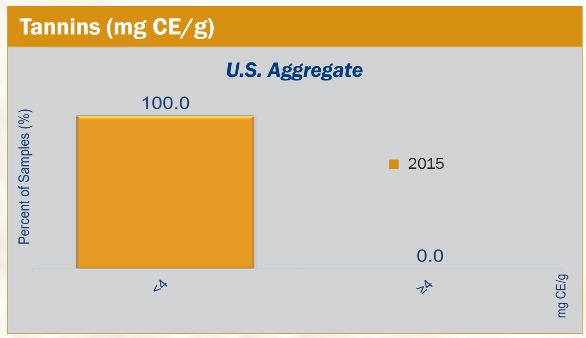
- Average oil concentration was higher for the NOLA EO (4.6%), with less variability than for the Texas EO (4.2%). Both averages fall in the normal range of reported oil concentration values.

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 phenolic molecules (catechins, epicatechins, etc.) and are widely distributed in nature (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 nutrients in the kernel. Livestock and poultry growth performance can be negatively affected by the 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[2,3].

RESULTS

- Tannin levels in all 2015/2016 U.S. Export Aggregate samples were measured to be less than 4.0 mg CE/g, implying an absence of tannins.



[2] *Awika, J.M. and L.W. Rooney. 2004. Sorghum phytochemicals and their potential impact on human health. Phytochemistry 65, 1199-1221.*
[3] *Price, M.L., S. Van Scoyoc and L.G. Butler. 1978. A critical evaluation of vanillin reaction as an assay for tannin sorghum. Journal of Agricultural and Food Chemistry 26, 1214-1218.*

V. EXPORT QUALITY TEST RESULTS (continued)

SUMMARY: CHEMICAL COMPOSITION

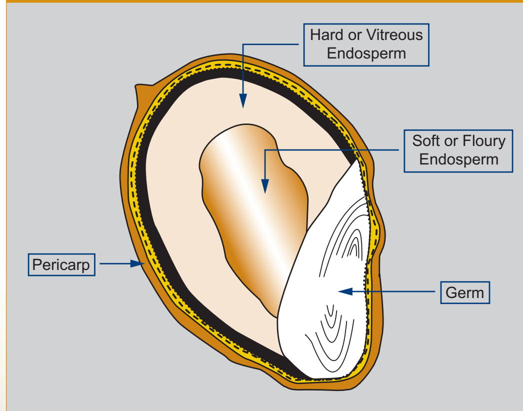
	2015/2016 Export Cargo				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Harvest Aggregate					
Protein (Dry Basis %)	182	10.8	0.51	9.7	12.6
Starch (Dry Basis %)	182	73.0**	0.38	71.4	75.0
Oil (Dry Basis %)	182	4.5	0.13	3.7	4.9
NOLA					
Protein (Dry Basis %)	46	10.8	0.51	9.7	12.1
Starch (Dry Basis %)	46	73.2	0.36	71.4	73.4
Oil (Dry Basis %)	46	4.6	0.10	3.7	4.7
Texas					
Protein (Dry Basis %)	136	10.8	0.51	9.9	12.6
Starch (Dry Basis %)	136	72.3	0.45	72.3	75.0
Oil (Dry Basis %)	136	4.2	0.25	4.4	4.9

*** Indicates that the 2015 Export Cargo averages were significantly different from 2015 Harvest averages, based on a 2-tailed t-test at the 95% level of significance.*

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.

Sorghum Kernel



Adapted from Rooney and Miller, 1982

SUMMARY: PHYSICAL FACTORS

- *For the U.S. Export Aggregate sorghum samples in 2015/2016, kernel diameter averaged 2.60 mm, TKW averaged 27.57 g, and kernel volume averaged 20.28 mm^3, all typical values for kernels from any sorghum sample, except kernel volume, which was on the lower end of the range of values cited in literature.*

- *In the 2015/2016 U.S. Export Aggregate samples, kernel true densities averaged 1.360 g/cm^3, which was within the range of feed sorghum.*

- *Kernel hardness index averaged 71.3 for U.S. Export Aggregate sorghum in 2015/2016, a typical value for any sorghum sample.*

- *Average values for kernel diameter, TKW, kernel volume, kernel true density, and kernel hardness index for the NOLA EO were higher than for the Texas EO. While there could be varietal and growing location differences between the EOs, no practical significance was tied to the consistent difference between EOs as all observed averages were within the range of values cited in literature for sorghum.*

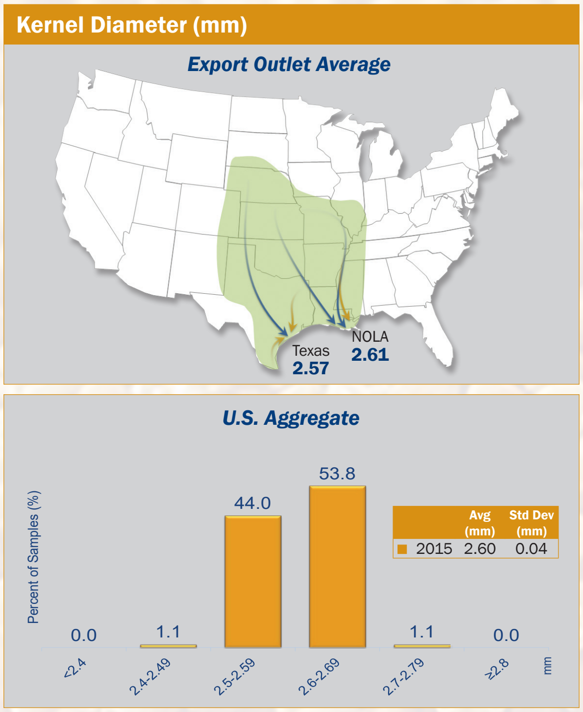
- *Average U.S. Aggregate values for kernel diameter, TKW, kernel volume, true density, and kernel hardness were somewhat higher at export than at harvest. The lower standard deviations for all of these tests at export indicated more uniformity at export than at harvest.*

1. Kernel Diameter

Kernel diameter (reported in mm) 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 2.60 mm for U.S. Export Aggregate sorghum in 2015/2016, a typical value for any sorghum sample.
- The kernel diameter values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.04 mm.
- Kernel diameters for the U.S. Export Aggregate samples ranged from 2.47 to 2.71 mm in 2015/2016.
- Average U.S. Export Aggregate kernel diameters were higher than that for U.S. Harvest Aggregate samples (2.53 mm). The standard deviation of export samples was much lower than that for the harvest samples (0.04 mm).
- In 2015/2016, U.S. Export Aggregate kernel diameters were distributed so that 1.1% of the samples had kernel diameters of 2.70 mm or greater, 97.8% were between 2.50 and 2.69 mm, and 1.1% were less than 2.50 mm.



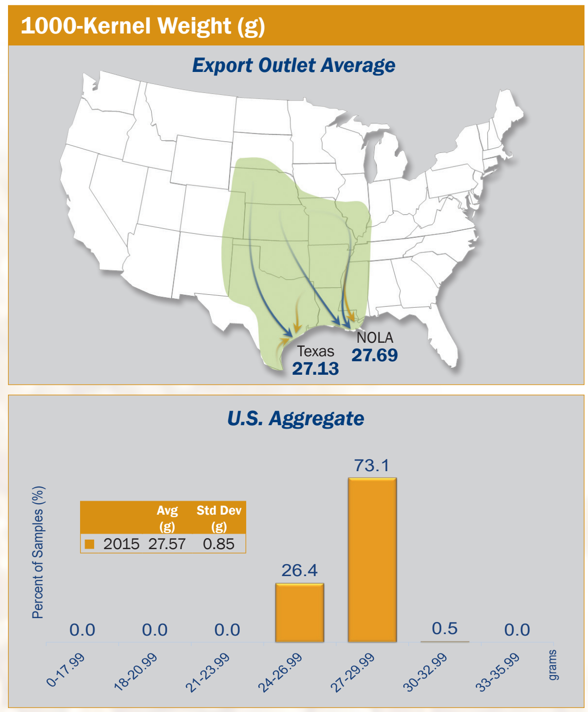
- Average kernel diameter was slightly higher for the NOLA EO (2.61 mm) than for the Texas EO (2.57 mm). Both averages fall in the normal range of reported kernel diameter values.

2. 1000-Kernel Weight (TKW)

1000-kernel weight (commonly referred to as TKW) is the weight for a fixed number of kernels, and is reported in g. Kernel volume (or size) can be inferred from TKW, since as TKW 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

- TKW averaged 27.57 g for U.S. Export Aggregate sorghum in 2015/2016, a value in the range of typical TKW values in literature for U.S. sorghum hybrids.
- The TKW values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.85 g.
- TKW for the U.S. Export Aggregate samples ranged from 24.28 to 30.02 g in 2015/2016.
- Average U.S. Export Aggregate TKW was higher than that for U.S. Harvest Aggregate samples (26.30 g). The standard deviation of export samples was much lower than that for the harvest samples (2.00 g).
- In the 2015/2016 U.S. Export Aggregate samples, TKW was distributed so that 0.5% of the samples had TKW of 30.00 g or greater and 99.5% had TKW between 24.00 and 29.99 g.



- Average TKW was higher for the NOLA EO (27.69 g), with less variability than for the Texas EO (27.13 g). Both averages fall in the normal range of reported TKW values.

V. EXPORT QUALITY TEST RESULTS (continued)

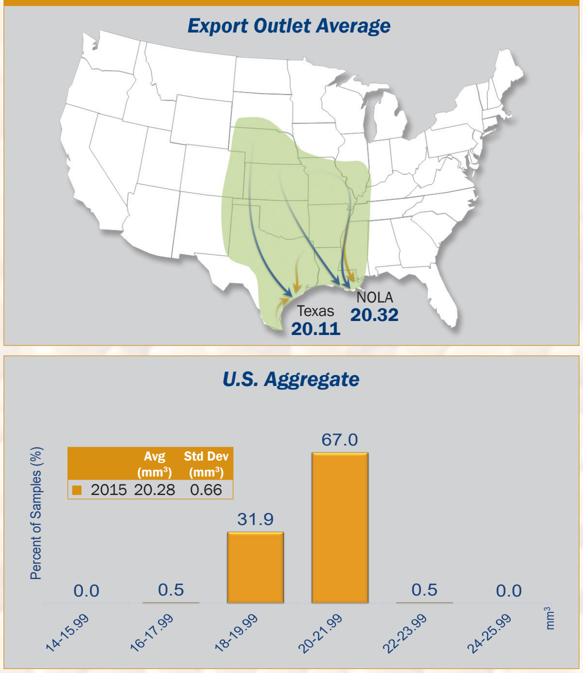
3. Kernel Volume

Kernel volume (or size), reported in mm^3, 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 20.28 mm^3 for U.S. Export Aggregate sorghum in 2015/2016, a value on the lower end of typical values for any sorghum sample.
- The kernel volume values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.66 mm^3.
- Kernel volumes for the U.S. Export Aggregate samples ranged from 17.91 to 22.12 mm^3 in 2015/2016.
- Average U.S. Export Aggregate kernel volumes were higher than that for U.S. Harvest Aggregate samples (19.34 mm^3). The standard deviation of export samples was much lower than that for the harvest samples (1.44 mm^3).
- In the 2015/2016 U.S. Export Aggregate samples, kernel volumes were distributed so that 0.5% of the samples had kernel volumes of less than 18.00 mm^3, 98.9% were between 18.00 and 21.99 mm^3, and 0.5% were equal to or greater than 22.00 mm^3.

Kernel Volume (mm^3)



- Average kernel volume was higher for the NOLA EO (20.32 mm^3), with less variability than for the Texas EO (20.11 mm^3). Both averages fall in the lower end of the normal range of reported kernel volume values.

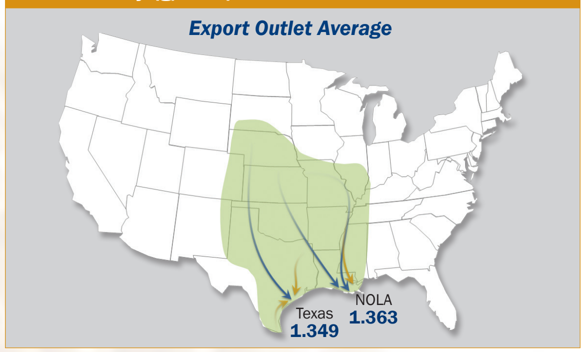
4. Kernel True Density

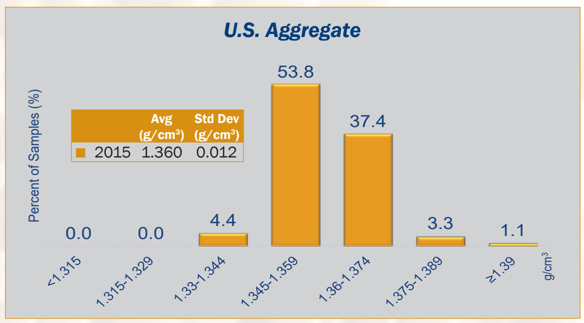
Kernel true density (kernel weight per kernel volume), reported as g/cm^3, is a relative indicator of kernel hardness, which is useful during size reduction operations. This quality factor is reported as g/cm^3. Genetics of the sorghum hybrid and the growing environment affect kernel true density. Sorghum 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 1.360 g/cm^3 for U.S. Export Aggregate sorghum in 2015/2016, which falls in the normal range for U.S. sorghum hybrids.
- The true density values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 0.012 g/cm^3.
- True densities for the 2015/2016 U.S. Export Aggregate samples ranged from 1.333 to 1.496 g/cm^3.
- Average U.S. Export Aggregate true densities were only slightly higher than those for U.S. Harvest Aggregate samples (1.359 g/cm^3). The standard deviation of export samples was about the same as that for the harvest samples (0.013 g/cm^3).
- In the 2015/2016 U.S. Export Aggregate samples, kernel true densities were distributed so that 4.4% of the samples were between 1.330 and 1.344 g/cm^3, 91.2% between 1.345 and 1.374 g/cm^3, and 4.4% greater than or equal to 1.375 g/cm^3.

True Density (g/cm^3)





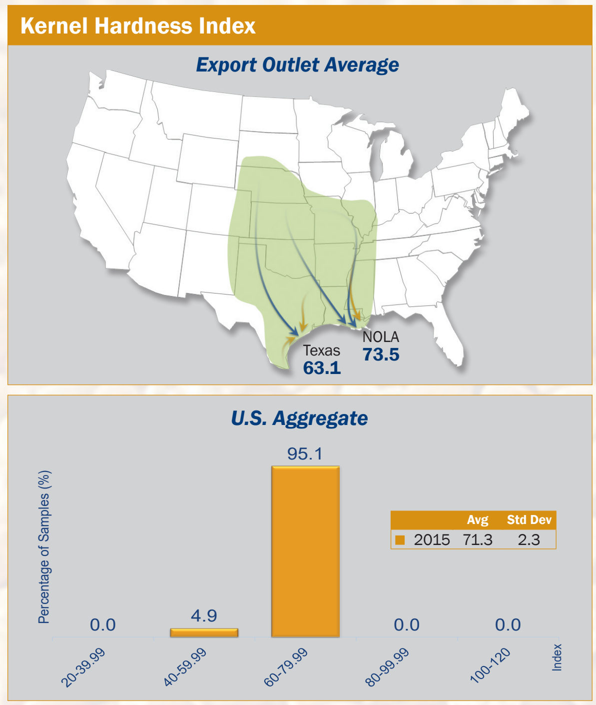
- Average kernel true density was higher for the NOLA EO (1.363 g/cm^3), with greater variability than for the Texas EO (1.349 g/cm^3). Both averages fall in the normal range of reported kernel true density values.

V. EXPORT QUALITY TEST RESULTS (continued)

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 as soft sorghum 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 71.3 for U.S. Export Aggregate sorghum in 2015/2016, which falls in the normal range for U.S. sorghum hybrids.
- The kernel hardness index values for the 2015/2016 U.S. Export Aggregate samples had a standard deviation of 2.3.
- Kernel hardness index for the U.S. Export Aggregate samples ranged from 55.6 to 79.8 in 2015/2016.
- Average U.S. Export Aggregate hardness index was slightly higher than the U.S. Harvest Aggregate samples (71.0). The standard deviation of export samples was much lower than that for the harvest samples (6.2).
- In the 2015/2016 U.S. Export Aggregate samples, kernel hardness indices were distributed so that 95.1% of the samples had kernel hardness indices of 60.00 to 79.99, and 4.9% had less than 60.00.
- Average kernel hardness index was higher for the NOLA EO (73.5), with less variability than for the Texas EO (63.1). Both averages fall in the normal range of reported kernel hardness index values.

SUMMARY: PHYSICAL FACTORS

	2015/2016 Export Cargo				
	No. of Samples	Avg.	Std. Dev.	Min.	Max.
U.S. Export Aggregate					
Kernel Diameter (mm)	182	2.60**	0.04	2.47	2.71
TKW (g)	182	27.57**	0.85	24.28	30.02
Kernel Volume (mm^3)	182	20.28**	0.66	17.91	22.12
True Density (g/cm^3)	182	1.360	0.012	1.333	1.496
Kernel Hardness Index	182	71.3	2.3	55.6	79.8
NOLA					
Kernel Diameter (mm)	46	2.61	0.04	2.47	2.67
TKW (g)	46	27.69	0.79	24.28	29.42
Kernel Volume (mm^3)	46	20.32	0.63	18.12	21.77
True Density (g/cm^3)	46	1.363	0.014	1.335	1.367
Kernel Hardness Index	46	73.5	2.0	55.6	71.4
Texas					
Kernel Diameter (mm)	136	2.57	0.04	2.48	2.71
TKW (g)	136	27.13	1.08	24.64	30.02
Kernel Volume (mm^3)	136	20.11	0.79	17.91	22.12
True Density (g/cm^3)	136	1.349	0.005	1.333	1.496
Kernel Hardness Index	136	63.1	3.5	67.9	79.8

*** Indicates that the 2015 Export Cargo averages were significantly different from 2015 Harvest averages, based on a 2-tailed t-test at the 95% level of significance.*

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 sorghum grain, aflatoxins and deoxynivalenol (DON or vomitoxin) are considered to be two of the important mycotoxins.

The U.S. grain merchandising industry implements strict safeguards for handling and marketing any elevated levels of mycotoxins. All stakeholders in the sorghum value chain – seed companies, sorghum growers, grain marketers and handlers, as well as U.S. sorghum export customers – are interested in understanding how mycotoxin infection is influenced by growing conditions and the subsequent storage, drying, handling and transport of the grain as it moves through the U.S. sorghum export system.

ASSESSING THE PRESENCE OF AFLATOXINS AND DON

To assess the effect of the above-mentioned conditions on aflatoxins and DON development, this report summarizes the results from official U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) aflatoxin tests and from independent aflatoxin and DON tests for all the export samples collected as part of this survey.

A threshold established by 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 LCL for the analytical kits approved by FGIS and used for this *2015/2016 Export Cargo Survey* was 5.0 parts per billion (ppb) for aflatoxins and 0.5 parts per million (ppm) for DON. Details on the testing methodology employed in this study for the mycotoxins are in the "Testing Analysis Methods" section.

RESULTS: AFLATOXINS

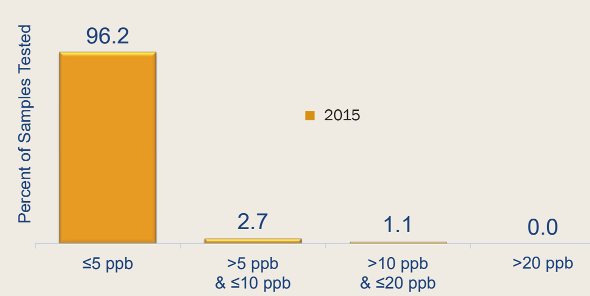
A total of 182 export samples were analyzed for aflatoxins for the *2015/2016 Export Cargo Survey*. Results of the 2015/2016 survey are as follows:

- One hundred seventy-five (175) samples or 96.2% of the 182 samples tested in 2015/2016 had no detectable levels of aflatoxins (defined as less than or equal to the FGIS LCL limit of 5 parts per billion (ppb)).
- Five (5) samples or 2.7% of the 182 samples tested in 2015/2016 had aflatoxin levels greater than 5 ppb, but less than or equal to 10 ppb.
- Two (2) samples or 1.1% of the 182 samples tested in 2015/2016 had aflatoxin levels greater than 10 ppb, but less than or equal to the Food and Drug Administration (FDA) action level of 20 ppb.
- 100% of the samples tested in 2015/2016 were below the FDA action level of 20 ppb.

Aflatoxins

	Percent of Total Samples				
	< 5 ppb	**≥ 5 to < 10 ppb**	**≥ 10 to ≤ 20 ppb**	**> 20 ppb**	**Total**
U.S. Aggregate	96.2%	2.7%	1.1%	0.0%	100.0%
By EO					
NOLA	95.7%	2.2%	2.2%	0.0%	100.0%
Texas	96.3%	2.9%	0.7%	0.0%	100.0%

Aflatoxin Testing Results



Most sample test results (98.9%) were less than or equal to 10 ppb, and a high percentage of sample test results (96.2%) were less than the FGIS LCL of 5.0 ppb.

RESULTS: DON (DEOXYNIVALENOL OR VOMITOXIN)

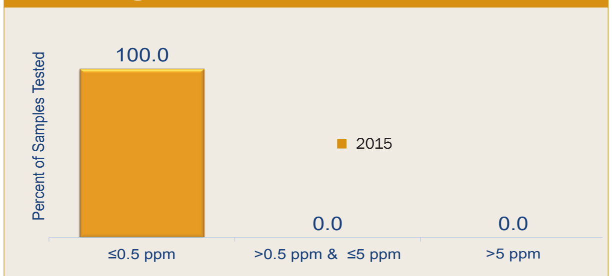
A total of 182 export samples were tested for DON for the 2015/2016 *Export Cargo Survey*. Results of the testing are shown below:

- All one hundred and eighty-two (182) samples, or 100.0%, had no detectable levels of DON (all samples tested less than or equal to the FGIS LCL of 0.5 ppm).
- None of the sample test results (0), or 0.0% of the 182 samples, tested greater than 0.5 ppm, but less than or equal to the FDA advisory level of 5 ppm.
- None of the sample test results (0), or 0.0% of the 182 samples, tested greater than the FDA advisory level of 5 ppm.

DON

	Percent of Total Samples			
	≤ 0.5 ppm	≥ 0.5 to ≤ 5.0 ppm	> 5.0 ppm	Total
U.S. Aggregate	100.0%	0.0%	0.0%	100.0%
By EO				
NOLA	100.0%	0.0%	0.0%	100.0%
Texas	100.0%	0.0%	0.0%	100.0%

DON Testing Results



1. Background: General

The levels at which the fungi produce mycotoxins are influenced by the fungus type and the environmental conditions under which the sorghum is produced and stored. Because of these differences, mycotoxin production varies across the U.S. sorghum-producing areas and across years.

Humans and livestock are sensitive to mycotoxins at varying levels. As a result, the 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 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 import 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 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 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", which can be found at *http://www.ngfa.org/wp-content/uploads/NGFAComplianceGuide-FDARegulatoryGuidanceforMycotoxins8-2011.pdf*.

2. Background: Aflatoxins

The most important type of mycotoxin associated with sorghum grain is aflatoxins. There are several types of aflatoxins produced by different species of the *Aspergillus* fungus, 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 plant and often penetrates kernels through wounds produced by insects.

There are four types of aflatoxins 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 type of aflatoxin in food and feed and is also the most toxic. Additionally, dairy cattle metabolize aflatoxins 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 in poultry and ducks, the most sensitive of the animal species. Livestock may experience reduced feed efficiency or reproduction, and both humans' and animals' immune systems may be suppressed due to aflatoxin ingestion.

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

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

If required by the buyer, sorghum exported from the United States will be tested for aflatoxins by FGIS. Sorghum above the FDA action level of 20 ppb or the buyer's specification cannot be exported unless other strict conditions are met. These requirements result 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

3. Background: DON (Deoxynivalenol or Vomitoxin)

DON is another mycotoxin of concern to some importers of sorghum grain. It is produced by certain species of *Fusarium*, the most important of which is *F. graminearum* (*Gibberella zeae*). *Gibberella zeae* can develop when cool or moderate and wet weather occurs at flowering. Mycotoxin contamination of sorghum caused by *Gibberella zeae* is often associated with excessive postponement of harvest and/or storage of high-moisture sorghum.

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 sorghum and may have low weight gain, diarrhea, lethargy and intestinal hemorrhaging. Additionally, DON 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 sorghum, the advisory levels are:

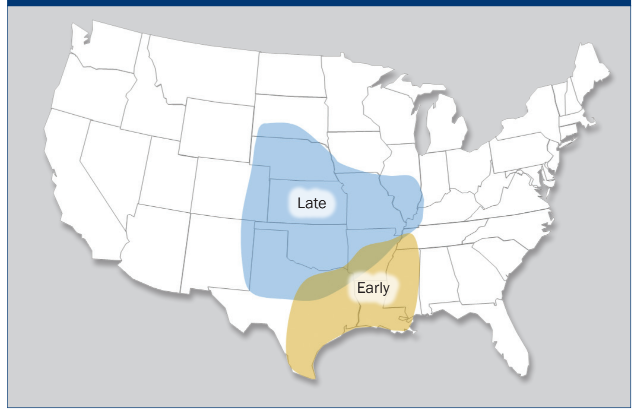
- 5 ppm in grains and grain co-products for swine, not to exceed 20% of their diet;
- 10 ppm in grains and grain co-products for chickens and cattle, not to exceed 50% of their diet; and
- 5 ppm in grains and grain co-products for all other animals, not to exceed 40% of their diet.

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

VI. CROP AND WEATHER CONDITIONS

Weather conditions before and at planting, throughout the growing season, and even during harvest play a major role in the evolution of the sorghum plant and ultimately in the sorghum grain yield and quality. For U.S. sorghum production, two main harvest areas, Early Harvest Area (EHA) and Late Harvest Area (LHA), are highlighted.

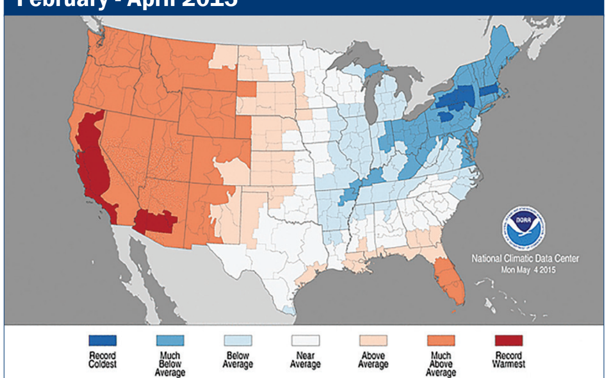
Harvested Area



For the Early Harvest Area (EHA), the 2015 growing season started late due to delayed planting. This was followed by a wet early-growth period (from planting until half-bloom) compared to a historical period of 1895 to 2015. Wet conditions lingered across the Texas coastal area of the EHA while drier conditions developed within the continental area[1] during the reproductive phase until harvest. The 2015 sorghum crop condition for the EHA improved as the growing season progressed from early in the season to harvest[2]. The following list highlights the key events of the EHA for the 2015 growing season:

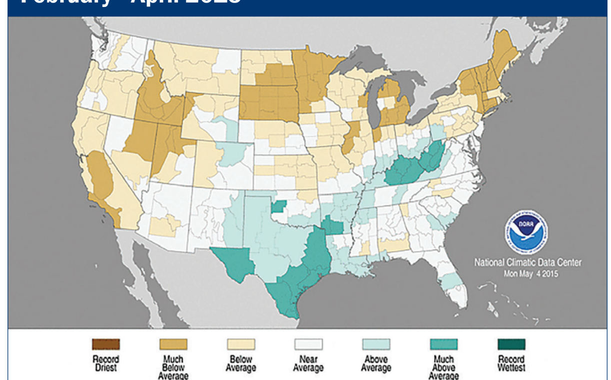
- Temperatures during the early planting time frame (from February until April) averaged near or below the historical averages, and provided cool temperatures for emergence conditions.
- Above-average moisture conditions during the early planting period and continued wet conditions (wettest on record) until mid-pollination (from February until June and July) slowed plant growth.
- Near-average temperatures in the continental area and above-average temperatures near the coastal areas from April to June potentially impacted crop development during the floret fertility and final grain formation stages, thereby possibly impacting yields.

Divisional Average Temperature Ranks (Period: 1895-2015) February - April 2015



Source: Regional Climate Centers

Divisional Precipitation Ranks (Period: 1895-2015) February - April 2015



Source: Regional Climate Centers

[1] *The continental area is the area in Texas that is not along the coast.*

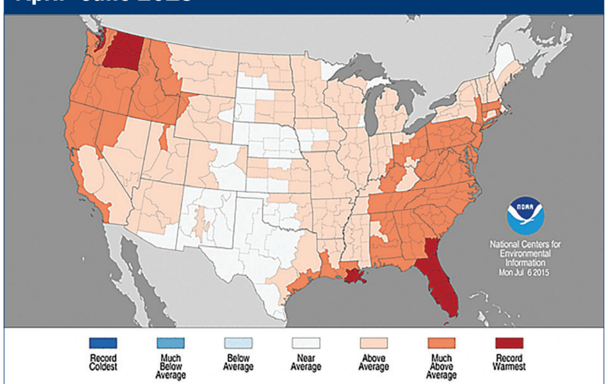
[2] *The U.S. Department of Agriculture (USDA) rates the U.S. sorghum crop weekly during the production cycle. The rating is based on yield potential, and plant stress due to a number of factors including extreme temperatures, excessive or insufficient moisture, disease, insect damage, and/or weed pressure.*

For the Late Harvest Area (LHA), the 2015 growing season experienced delayed planting due to wet conditions during the early part of the typical planting season (April until June). This was coupled with average or above-average temperatures compared to historical temperature averages (1985 – 2015). The 2015 sorghum crop condition for the LHA remained fairly constant from the early vegetative stages until harvest. The following list highlights the key events of the LHA for the 2015 growing season:

- Non-uniform precipitation events during planting time (May through June) produced well-above-average wet conditions in some areas and near- or just-above-average conditions in other areas. These conditions caused delayed and slow planting progress.
- Near- and above-average temperatures from April to June helped with planting progress and emergence.
- Heavy rainfall and normal-to-cool temperatures from the vegetative to early reproductive phase presented a challenge for growing conditions by slowing crop growth and delaying sorghum heading in some areas.
- Slow growth conditions around pollination favored floret fertility and the grain formation process, thereby diminishing the impact of any stress that might have occurred at this stage.
- In most of the LHA, temperatures for the mid-pollination period were cooler than normal, while temperatures for grain filling in September were warmer than normal.
- Warm temperatures and dry conditions from grain filling to harvest accelerated maturity and natural drying, and hastened harvesting during October.

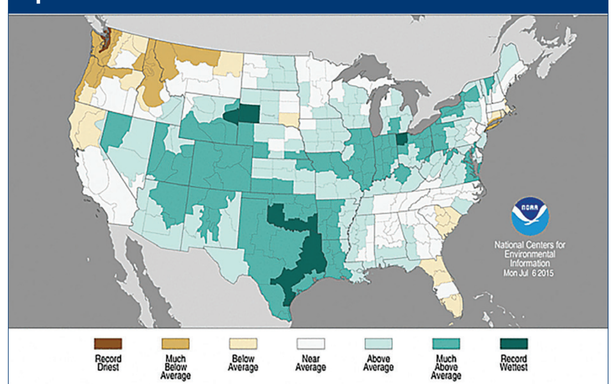
The following sections describe how the 2015 growing-season weather impacted the sorghum development and yield for both the Early and Late Harvest Areas in the U.S. sorghum production regions.

Divisional Average Temperature Ranks
(Period: 1895-2015)
April - June 2015



Source: Regional Climate Centers

Divisional Precipitation Ranks
(Period: 1895-2015)
April - June 2015



Source: Regional Climate Centers

A. Planting and Early Growth Conditions

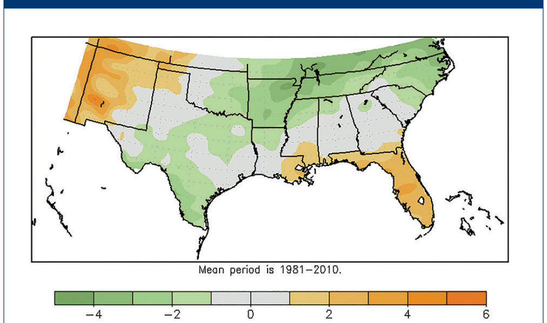
Abundant rain delayed planting time

Weather, primarily precipitation and temperature, affects sorghum growth and development from pre-planting through harvest. Weather factors present a complex interaction with the genotype (sorghum hybrids) and management practices (i.e., planting date, soil fertility, pesticide applications) utilized in sorghum production. Grain yield in sorghum is a function of number of plants per acre, number of tillers[3] per plant, number of grains per head, and final seed weight per individual grain. Wet and cool planting conditions can decrease uniformity, delay emergence, or hinder early plant growth, which may result in a lower number of plants and/or lower yields per area. Sorghum can compensate for small stand reductions via tillering capacity. Drier and warmer conditions than normal early in the growing season are beneficial for proper root establishment and plant-to-plant uniformity. This is because these conditions promote the development of deeper root systems for adequate anchorage and sustain continuous access to water and nutrients during the growing season.

1. Early Harvest Area

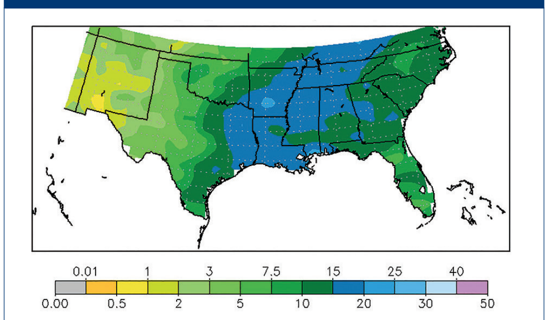
Overall, early planting conditions from February to April in the EHA were impacted by relatively below-normal or normal temperatures and much-above-normal precipitation (more than 10 inches of excess moisture). These conditions promoted a very slow start to the planting season, with almost no planting progress until March.

Average Temperature (°F): Departure from Mean February 1, 2015 to April 30, 2015



Source: Regional Climate Centers

Accumulated Precipitation (in) February 1, 2015 to April 30, 2015



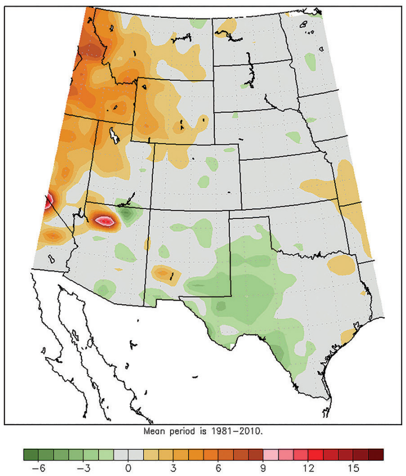
Source: Regional Climate Centers

[3] *Tillers are stems smaller than the main plant stalk that can also develop fertile heads.*

2. Late Harvest Area

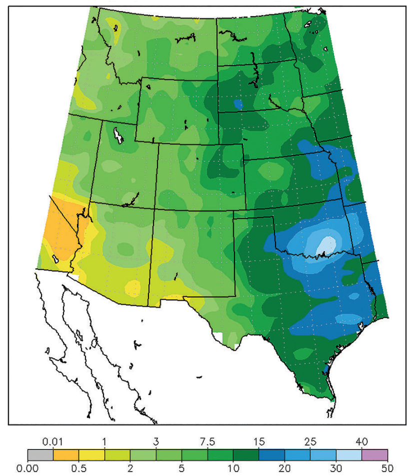
Planting was also delayed in the LHA due to wet conditions during May to June, despite normal temperatures. The 2015 LHA planting season spanned from April until July, with the largest progress made during June. For some areas in the LHA, this three-month interval was the wettest on record, slowing down planting and early plant growth. The abundant rain also may have affected root establishment by inducing stunted plants and fertility loss, as well as by diminishing favorable early crop conditions.

Average Temperature (°F): Departure from Mean
May 1, 2015 to June 30, 2015



Source: Regional Climate Centers

Accumulated Precipitation (in)
May 1, 2015 to June 30, 2015



Source: Regional Climate Centers

B. Late Vegetative and Mid-Pollination Conditions

Record wet conditions and cool summer slowed growth but favored pollination

The amount of time between emergence and half-bloom[4] depends on the planting date, the temperatures during this period (of which the impact is measured by growing degree days[5]), and the sorghum hybrid. High temperature stress after growing point differentiation (approximately 30 days after emergence) delays heading[6] and decreases seed set (number and size of seeds), affecting final yields. Delayed planting may result in delayed blooming (or flowering). Blooming later than normal during the growing season increases the likelihood of the crop being exposed to excessive heat at blooming, which could jeopardize yields and final grain numbers. Temperatures below 40°F during grain fill can negatively impact the ability of the plant to fill the grains, thus affecting final yields. Hybrid selection also affects the length of time from planting until mid-pollination; short-season hybrids have a shorter time from emergence to flowering than the full-season hybrids, and therefore have lower yield potential compared to the full-season hybrids.

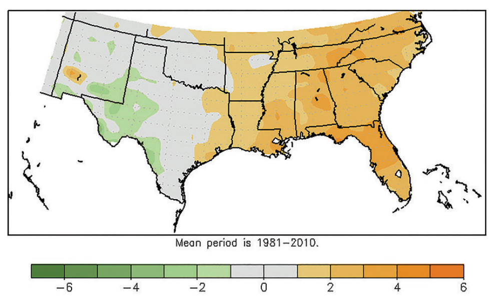
[4] *Half-bloom is the sorghum reproductive stage where 50% of the plants in the field are in some stage of bloom.*
[5] *Growing degree days is a parameter related to heat accumulation in order to predict plant development stages.*
[6] *Heading, the process in which sorghum heads are exerted and visible on the plant tops, occurs after boot stage and before flowering.*

VI. CROP AND WEATHER CONDITIONS (continued)

1. Early Harvest Area

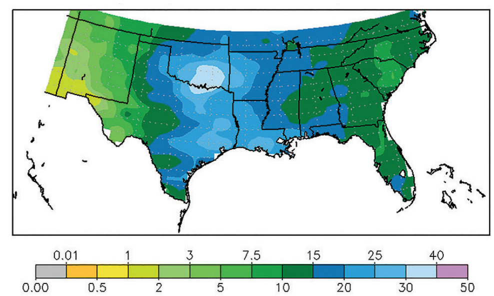
Sorghum heading in the EHA took place from mid-July to the onset of August. Cool and wet conditions (more than 20 inches of excessive rain) dominated during the vegetative phase and the half-bloom stage. These conditions slowed plant growth and reduced nutrient uptake (thereby affecting the root systems) during the vegetative phase. However, the cool temperatures favored the blooming process, resulting in more grains per head. While normal or slightly above-average temperatures occurred during the grain fill period, the main challenge for crop development remained the wet conditions.

Average Temperature (°F): Departure from Mean April 1, 2015 to June 30, 2015



Source: Regional Climate Centers

Accumulated Precipitation (in) April 1, 2015 to June 30, 2015

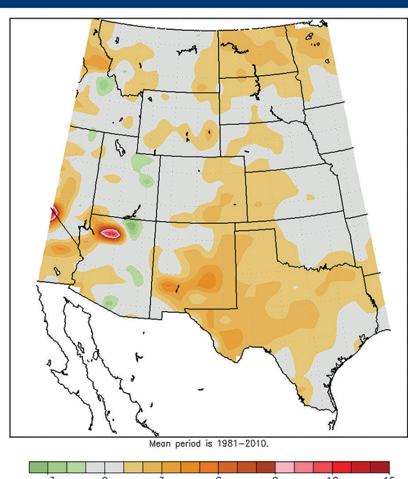


Source: Regional Climate Centers

2. Late Harvest Area

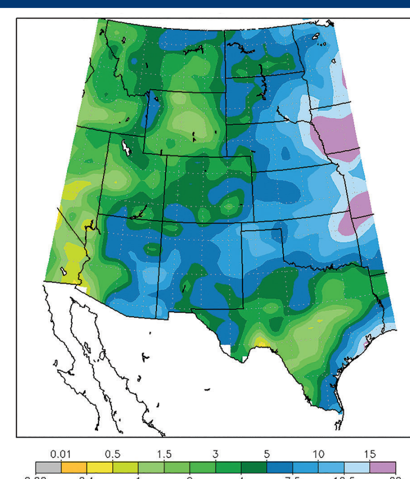
Sorghum heading for the LHA spanned from mid-August to early October, with the largest percentage occurring during September. For the northern section of this area, if flowering took place early- to mid-September, the probability of reaching maturity before the first freeze was lowered due to the lack of accumulation of growing degree days. Late vegetative phase conditions and half-bloom phase remained wet with normal temperatures. Conditions for the grain fill period across the entire LHA changed from very wet to dry, and average temperatures were normal to above-normal. These conditions shortened grain fill and accelerated maturity.

Average Temperature (°F): Departure from Mean July 1, 2015 to September 30, 2015



Source: Regional Climate Centers

Accumulated Precipitation (in) July 1, 2015 to September 30, 2015



Source: Regional Climate Centers

C. Maturity and Harvest Conditions

Warm weather and drier conditions shortened grain-fill and hastened harvest

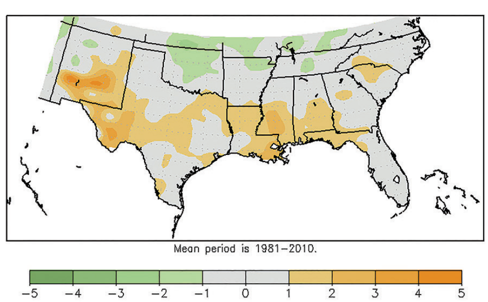
When the sorghum plant reaches physiological maturity (or black layer), the grain achieves its final maximum dry mass and nutrient content. Prior to reaching the black layer stage, freezing temperatures could lower test weight (through small seeds), impede final maturity, and consequently reduce yields. Once maturity has been reached and until harvest time, sorghum grain will dry down from about 35% to around 20% moisture. The dry-down rate is influenced by hybrid maturity, grain moisture at the beginning of dry down, and temperature during the dry-down period. If sorghum does not dry down sufficiently, the higher-moisture grain remains soft and becomes more susceptible to pericarp breakage as well as more difficult to thresh.

1. Early Harvest Area

Typically, 80% of the sorghum in the EHA is harvested by the end of August. However, in 2015, similar harvest progress was achieved approximately a week later than normal. Despite delayed planting in this area, drier and warmer weather after mid-pollination hastened maturity and harvest. For this region, freeze is not an issue.

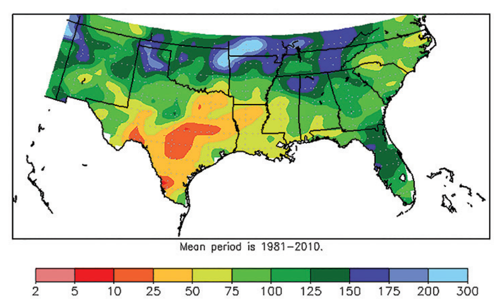
The main production issue in the EHA in 2015 was related to the sugarcane aphid (*Melanaphis sacchari),* which infested and damaged some of the crop. The infestation of this pest can impact plant health, seed weight, yield, and ultimately grain quality. Since its presence is new in this area, the degree to which it affects yield and quality is still being determined.

Average Temperature (°F): Departure from Mean
July 1, 2015 to August 31, 2015



Source: Regional Climate Centers

Accumulated Precipitation: Percent of Mean
July 1, 2015 to August 31, 2015



Source: Regional Climate Centers

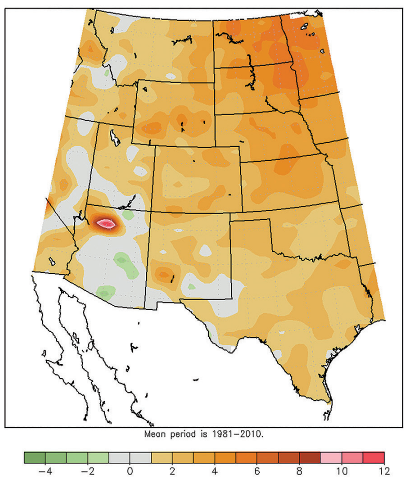
2. Late Harvest Area

Close to 80% of the LHA sorghum crop is usually harvested by the beginning of November. Harvest progress in 2015 was comparable to the average for the 2010-2014 period. Despite the 2015 LHA crop's late start, its comparable harvest progress to the 2010-2014 period was due to the warmer and drier late reproductive weather conditions in 2015. There was also no widespread early freeze that would have slowed maturity and possibly enabled pericarp-cracked grain or led to harvest and disease issues.

The wet conditions in the early part of the LHA growing season caused poor root establishment and compaction problems in some areas. In addition, the dry, warm conditions from mid-grain filling to harvest increased nutrient remobilization to the grains and weakened the stalks. The combination of these two sets of conditions increased the susceptibility of the sorghum plants in the LHA to fungal diseases such as charcoal rot and *Fusarium* stalk rot, and to lodging issues (the leaning or falling over of the plant).

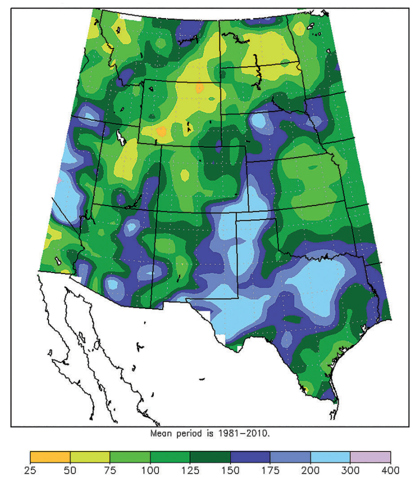
Similar to the EHA, the sugarcane aphid (*Melanaphis sacchari)* advanced far north and impacted sorghum production, primarily from the mid-vegetative to late reproductive stages, in areas of Oklahoma and Kansas. The presence of aphids in the EHA impacted yields and sorghum grain quality.

Average Temperature (°F): Departure from Mean
September 16, 2015 to November 30, 2015



Source: Regional Climate Centers

Accumulated Precipitation: Percent of Mean
September 16, 2015 to November 30, 2015



Source: Regional Climate Centers

D. Comparison of 2015 to 2010-2014

2015 delayed planting, early wet conditions, with comparable harvest time

1. Early Harvest Area

While the average 50% planting progress date for 2010-2014 was around the end of March, producers in the EHA reached 50% planting progress approximately seven to ten days later in 2015. However, EHA planting progress in 2015 quickly caught up to the average 80% planting progress for 2010-2014. Abundant rains from late February (when early planting could start) until mid-pollination time (June) delayed vegetative growth. These rains were the primary cause of the EHA sorghum crop reaching the 50% mid-pollination crop progress approximately two weeks behind the average for 2010-2014. From the late reproductive phase through harvest, drier and warmer grain-fill conditions hastened maturity and harvesting, with the 2015 harvest only one week behind the 2010-2014 average. For the EHA, freeze events were not of main concern for reducing yields and impacting grain quality.

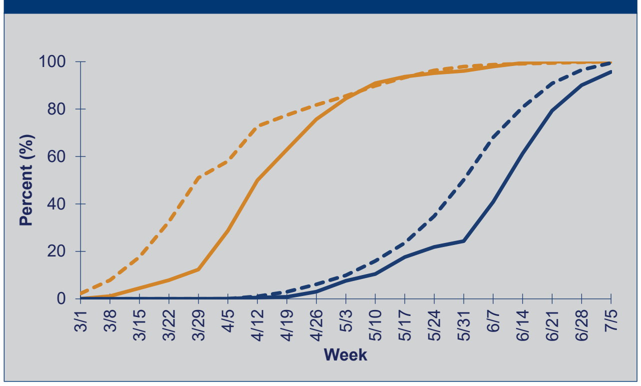
Throughout much of the 2015 season, the sorghum crop in the EHA was below the 60% crop condition rating. This rating reflected the challenges in sorghum production experienced early in the 2015 growing season, including wet early-season conditions, which caused delayed planting; cool temperatures, which slowed vegetative development; increased nutrient losses; and lowered biomass accumulation (or plant growth). Crop conditions improved as the EHA sorghum approached mid-pollination with a 70% crop condition rating. This average crop rating remained at the same level until harvest.

2. Late Harvest Area

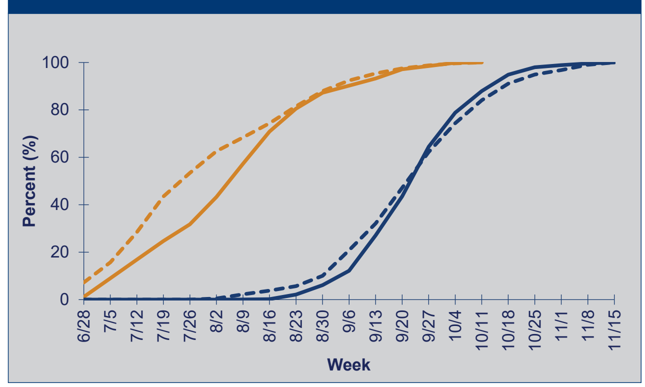
In 2015, sorghum producers experienced onset and early planting progress from early April until mid-May, comparable to the averages for 2010-2014. While abundant rains from early May until approximately mid-June delayed overall planting progress in 2015 compared to the average for 2010-2014, 2015 planting progress was comparable to the 2010-2014 average at the 80% planting progress threshold. Drier weather then prevailed in 2015 from mid-to-late June until heading, which accelerated late vegetative stages and caused the crop to reach mid-pollination at about the same time as the average for 2010-2014. In 2015, heading started in early August, reaching 50% around mid-September and 100% close to the beginning of October. From the late reproductive phase until harvest, drier and warmer grain-fill conditions hastened maturity and harvest time, with crop progress for the 2015 growing season comparable to the averages for 2010-2014. Freeze events are of concern for reducing yields in the LHA, but were not a problem for the 2015 growing season.

The 2015 LHA sorghum crop condition rating was approximately 70% from early planting until harvest. This crop condition rating implied good plant health, normal vegetative development, and good plant growth. Average crop condition for the 2010-2014 period was below 50%, which clearly portrayed a better growing season for 2015 compared to the average for the 2010-2014 period. The more favorable sorghum conditions in 2015 were also reflected in higher yields documented for this crop year.

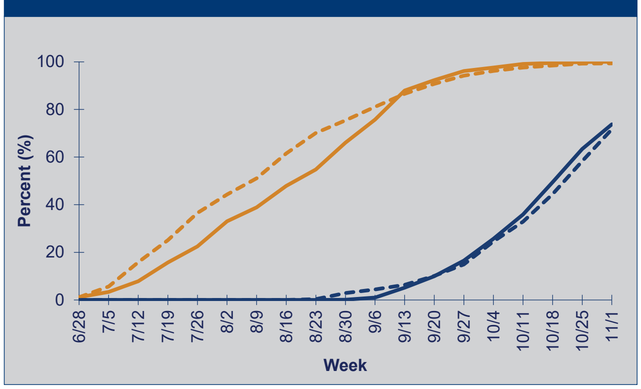
Percent Planted



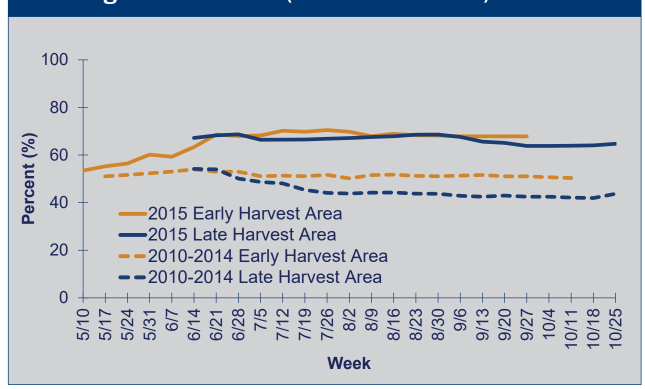
Percent Headed



Percent Harvested



U.S. Sorghum Conditions (Rated Good + Excellent) %



VII. U.S. SORGHUM EXPORT SYSTEM

This U.S. Grains Council's *2015/2016 Sorghum Harvest & Export Cargo Quality Report* provides advance information about sorghum quality by evaluating and reporting quality attributes when the sorghum is ready to be loaded onto the vessel or railcar for export. Sorghum quality includes a range of attributes that can be categorized as:

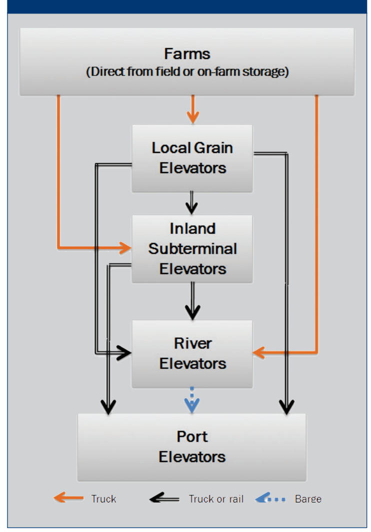
- Intrinsic quality characteristics – Protein, oil, starch and tannin content, hardness and density are all considered to be intrinsic quality characteristics; that is, they are contained within and of critical importance to the end user. Since they are non-visual, these characteristics can only be determined by analytical tests.
- Physical quality characteristics – These attributes are associated with outwardly visible appearance of the kernel or measurement of the kernel characteristics. Characteristics include kernel size, shape and color, moisture, test weight, total damaged and heat-damaged kernels, and broken kernels. Some of these characteristics are measured when sorghum receives an official USDA grade.
- Sanitary quality characteristics – These characteristics indicate the cleanliness of the grain. Attributes include presence of foreign material, odor, dust, rodent excreta, insects, residues, fungal infection, and non-millable materials.

The intrinsic quality characteristics are impacted significantly by genetics and growing-season conditions, and typically do not change at the aggregate level as sorghum moves through the marketing system. On the other hand, the physical and sanitary characteristics can change as sorghum moves through the market channel. The parties involved in sorghum marketing and distribution use technologies (such as cleaning, drying, and conditioning) at each step in the channel to increase uniformity and to prevent or minimize the loss of physical and sanitary quality. The *2015/2016 Harvest Survey* portion of the report assessed the quality of the 2015 sorghum crop as it entered the marketing system and reported the crop as very good, with no incidences of aflatoxins and DON. The *2015/2016 Export Survey* portion of the report provides information on the impact of the subsequent practices, including cleaning, drying, handling, blending, storing, and transporting of the crop at the point where it is being loaded for export. To provide the backdrop for this assessment, the following sections describe the market channel from farm to export, the practices applied to sorghum as it moves through the market channel, and the implication of these practices on sorghum quality. Lastly, the inspection and grading services provided by the U.S. government are reviewed.

A. U.S. Sorghum Export Flow

As sorghum is harvested, farmers transport grain to on-farm storage, end users, or commercial grain facilities. While some producers feed their sorghum to their livestock, the majority of the sorghum moves to other end users (feed mills or processors) or to commercial grain handling facilities such as local grain elevators, inland subterminals, river elevators, and port elevators. Local grain elevators typically receive most of their grain directly from farmers. Inland subterminals or river elevators collect grains in quantities suitable for loading on unit trains or barges for further transport. These elevators are often located where the transport of bulk grain can be easily accommodated by unit trains or barges. Local grain, inland subterminal, and river elevators provide functions such as drying, cleaning, blending, storing, and merchandising of grain. River elevators and the larger inland subterminals supply most of the sorghum destined for export markets. The figure to the right conveys the flow of U.S. sorghum destined for export markets.

U.S. Sorghum Export Flow



B. Impact of the Sorghum Market Channel on Quality

While the U.S. sorghum industry strives to minimize changes in the physical and sanitary quality attributes as sorghum moves from the farm to export, there are points in the system where quality changes inevitably occur due to the biological nature of the grain. The following sections provide some insight on the reasons sorghum quality may change as sorghum moves from the field to the railcar or ocean vessel.

1. Drying and Conditioning

Farmers try to harvest sorghum with low moisture content, which may be less than 16%. Since these levels are close to sorghum's safe storage levels, which are usually about 13 to 14%, only minimal amounts of drying and conditioning are generally necessary for sorghum to be safe for storage and transport. Conditioning involves the use of aeration fans to control both temperature and moisture, which are important to monitor for storage stability. Drying and conditioning may occur either on a farm or at a commercial facility. When sorghum is dried, it can be dried by systems using natural air, low-temperature, or high-temperature drying methods. However, high-temperature drying is utilized far less with sorghum than with corn.

2. Storage and Handling

In the United States, sorghum storage structures can be broadly categorized as upright metal bins, concrete silos, flat storage inside buildings, or flat storage in on-ground piles. Upright bins and concrete silos with fully perforated floors or in-floor ducts are the most easily managed storage types because they allow aeration with uniform airflow through the grain. Flat storage can be used for short-term storage, which occurs most often when sorghum production is higher than normal and surplus storage is needed. However, it is more difficult to install adequate aeration ducts in flat types of storage, and they often do not provide uniform aeration. In addition, on-ground piles are sometimes not covered and may be subjected to weather elements that can result in mold damage.

Handling equipment can involve vertical conveying by bucket elevators, as well as horizontal conveying, usually by belt or en-masse conveyors. Regardless of how the sorghum is handled, some sorghum breakage will occur. The rate of breakage will vary by types of equipment used, severity of the grain impacts, grain temperature and moisture content, and by sorghum quality factors such as kernel hardness. As breakage levels increase, more broken pieces of sorghum are created, which leads to less uniformity in aeration and ultimately to higher risk for fungal invasion and insect infestation.

3. Cleaning

Cleaning sorghum involves scalping or removing large non-sorghum material and sieving to remove small, shriveled kernels, broken pieces of kernels, and fine materials. This process reduces the amount of broken kernels and foreign material found in the sorghum. The potential for breakage and initial percentages of broken kernels, along with the desired grade factor, dictate the amount of cleaning needed to meet contract specifications. Cleaning can occur at any stage of the market channel.

4. Transporting Sorghum

The U.S. grain transportation system is arguably one of the most efficient in the world. It begins with farmers transporting their grain from the field to on-farm storage or local grain and river elevators using either large wagons or trucks. Sorghum is then transported by truck, rail or barge to its next destination. Once at export facilities, sorghum is loaded onto ocean-going vessels or railcars. As a result of this complex yet flexible marketing system, sorghum may be loaded and unloaded several times, increasing its susceptibility to broken kernels and breakage.

Sorghum quality changes during shipment in much the same manner as it changes during storage. Causes of these changes include moisture variability (non-uniformity) and moisture migration due to temperature differences, high humidities and air temperatures, fungal invasion, and insect infestation. However, there are some factors affecting grain transportation that make quality control during transport more difficult than in fixed storage facilities. First, few modes of transport are equipped with aeration; consequently, corrective actions for heating and moisture migration cannot take place during transport. Another factor is the accumulation of fine material (spout-lines) beneath the loading spout when loading railcars, barges and ocean vessels. This results in whole kernels tending to roll to the outer sides, while fine material segregates in the center. A similar segregation occurs during the unloading process at each step along the way to final destination.

5. Implications on Quality

The intrinsic quality attributes such as protein cannot be altered within a sorghum kernel. However, as sorghum moves through the U.S. sorghum market channel, sorghum from multiple sources is mixed together. As a result, the average for a given intrinsic quality characteristic is affected by the quality levels of the sorghum from the multiple sources. The above-described marketing and transportation activities inevitably alter the various physical and sanitary quality characteristics. The quality characteristics that can be directly affected include test weight, damaged kernels, broken kernels, kernel size, moisture contents and variability, foreign material, and mycotoxin levels.

C. U.S. Government Inspection and Grading

1. Purpose

Global sorghum supply chains need verifiable and consistent oversight measures that fit the diverse needs of all end users. Oversight measures, implemented through standardized inspection procedures and grading standards, are established to provide:

- Information for buyers about grain quality at the time of loading prior to arrival at destination; and
- Food and feed safety protection for the end users.

The United States is recognized globally as having a combination of official grades and standards that are used for exporting grains and referenced in export contracts. U.S. sorghum sold by grade and shipped in foreign commerce must be officially inspected and weighed by the U.S. Department of Agriculture (USDA) Federal Grain Inspection Service (FGIS) or an official service provider delegated or designated by FGIS to do so (with a few exceptions). Unlike corn, sorghum exports are not required to be tested for aflatoxins; however, contracting parties often specify shipments to be tested. Qualified state and private inspection agencies are permitted to be designated by FGIS as official agents to inspect and weigh sorghum at specified interior locations. In addition, certain state inspection agencies can be delegated by FGIS to inspect and weigh grain officially at certain export facilities. Supervision of these agencies' operations and methodologies is performed by FGIS's field office personnel.

2. Inspection and Sampling

The loading export elevator provides FGIS or the delegated state inspection agency with a load order specifying the quality of the sorghum to be loaded as designated in the export contract. The load order specifies the U.S. grade and all other requirements that have been agreed upon in the contract between the foreign buyer and the U.S. supplier, plus any special requirements requested by the buyer such as minimum protein content, maximum moisture content, or other special requirements. The official inspection personnel determine and certify that the sorghum loaded in the vessel or railcar actually meets the requirements of the load order. Independent laboratories can be used to test for quality factors not mandated to be performed by FGIS, or for which FGIS does not have the local ability to test.

Shipments or “lots” of sorghum are divided into “sublots.” Representative samples for grading are obtained from these sublots using a diverter sampling device approved by FGIS. This device takes an incremental portion every 500 bushels (about 12.7 metric tons) from the moving grain stream just after the final elevation before filling into a shipping bin or loading into the ship or railcar. The incremental portions are combined by sublot and inspected by licensed inspectors. The results are entered into a log and, typically, a statistical loading plan is applied to ensure not only that the average result for each factor meets the contract specifications, but also that the lot is reasonably uniform in quality. Any sublot that does not meet uniformity criteria on any factor must be returned to the elevator or certified separately. The average of all sublot results for each factor is reported on the final official certificate. The FGIS sampling method provides a truly representative sample, while other commonly used methods may yield non-representative samples of a lot due to the uneven distribution of sorghum in a truck, railcar, or in the hold of a vessel.

3. Grading

Sorghum is divided into four U.S. numerical grades and U.S. Sample Grade. Each grade has limits for test weight, broken kernels and foreign material (BNFM), foreign material (a subset of BNFM), total damaged kernels, and heat-damaged kernels. Heat-damaged kernels are a subset of total damage. The limits for each grade are summarized in the table shown in the “U.S. Sorghum Grades and Conversions” section on page 83. In addition, if requested, FGIS provides certification of moisture content and other attributes such as protein, oil, and mycotoxins. Export contracts for sorghum specify many conditions related to the cargo in addition to the contract grade. In some cases, independent labs are used to conduct tests not required by FGIS.

Since the limits on all official grade factors (such as test weight and total damage) cannot always be met simultaneously, some grade factors may be better than the limit for a specified grade, but they cannot be worse. For example, a lot may meet the requirements for U.S. No. 2 except for one factor which would cause it to grade U.S. No. 3. For that reason, most contracts are written as “U.S. No. 2 or better” or “U.S. No. 3 or better.” This permits some grade factor results to be at or near the limit for that grade, while other factor results are “better than” that grade.

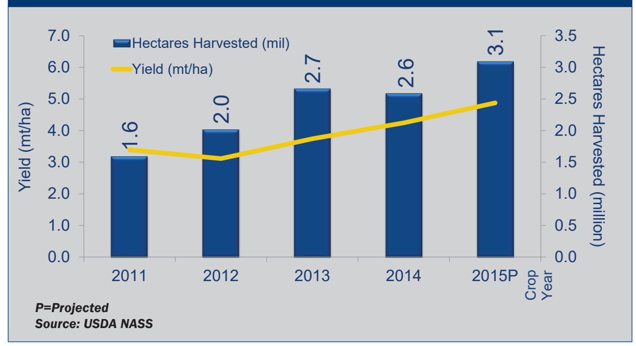
VIII. U.S. SORGHUM PRODUCTION, USAGE AND OUTLOOK

A. U.S. Sorghum Production[1]

1. U.S. Average Production and Yields

- According to the December 2015 U.S. Department of Agriculture (USDA) World Agricultural Supply and Demand Estimates (WASDE) report, average U.S. sorghum yield for the 2015 crop is projected to be 4.9 mt/ha (77.7 bu/ac). This is 0.6 mt/ha (10.1 bu/ac) higher than the 2014 sorghum crop, and is the highest average yield on record.

U.S. Sorghum Yield and Harvested Area

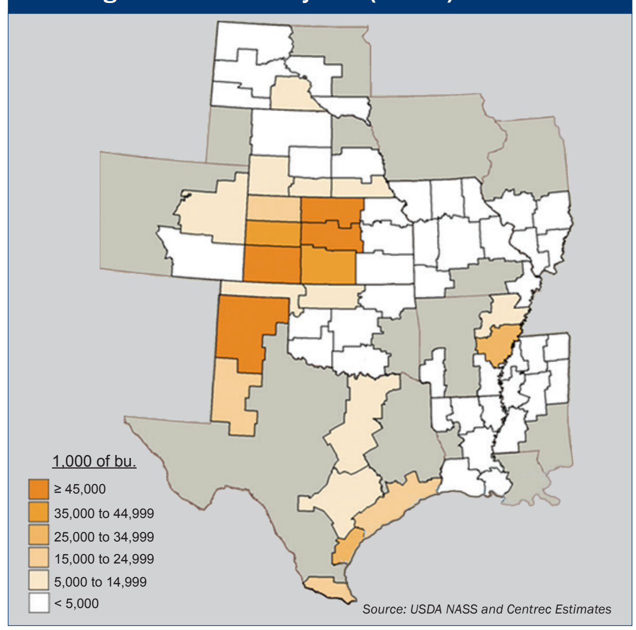


- The number of hectares harvested in 2015 is projected to be 3.1 million (7.6 mil ac). This is 0.5 mil ha (1.2 mil ac) more than in 2014. The projected 3.1 mil ha harvested in 2015 is the highest since 2003.
- Total U.S. sorghum production for 2015 is projected to be 15.1 mmt (593.8 mil bu). This is about 4.1 mmt (161.2 mil bu) higher than 2014, and is the highest since 1999.
- After producing the smallest crop since 1956 in 2011, sorghum production has sharply rebounded. With the most harvested hectares in more than a decade and the highest average yield on record, the 2015 sorghum crop is projected to be the largest in the past 16 years.

2. ASD and State-Level Production

The geographic areas included in the *2015/2016 Harvest Survey* encompass the highest sorghum-producing areas in the United States. This can be seen on the map showing projected 2015 sorghum production by USDA Agricultural Statistical District (ASD).

U.S. Sorghum Production by ASD (2015P)

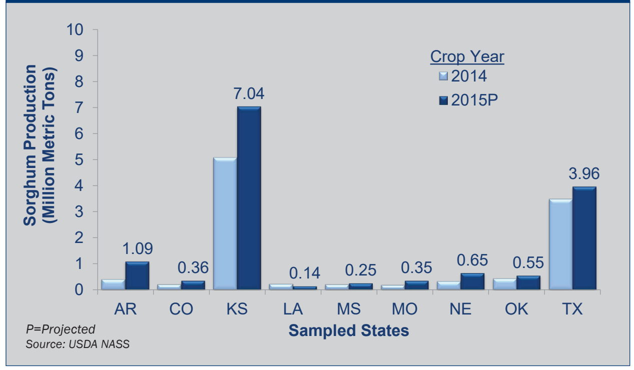


[1] *mt - metric ton; mmt - million metric tons; ha - hectare; bu - bushel; mil bu - million bushels; ac - acre.*

VIII. U.S. SORGHUM PRODUCTION, USAGE AND OUTLOOK *(continued)*

Relative to the sorghum crop produced in 2014, the increased size of the 2015 crop was primarily driven by higher production in Kansas, Arkansas, and Texas compared to 2014. Of the remaining six states, only Louisiana had lower production in 2015 than in 2014.

U.S. Sorghum Production by State



P=Projected
Source: USDA NASS

The U.S. Sorghum Production table summarizes the differences in both quantity (mmt) and percentages between 2014 and projected 2015 sorghum production for each state. Also included is an indication of the relative changes in harvested acres and yield between 2014 and projected 2015. The green bar indicates a relative increase and the red bar indicates a relative decrease from 2014 to projected 2015. This illustrates that harvested acres were higher across the board, with the exception of Louisiana. Yield changes were also generally higher, with large increases (greater than 10%) in Colorado, Kansas, and Nebraska. Louisiana was the only state surveyed that experienced a large yield decrease (greater than 10%).

U.S. Sorghum Production

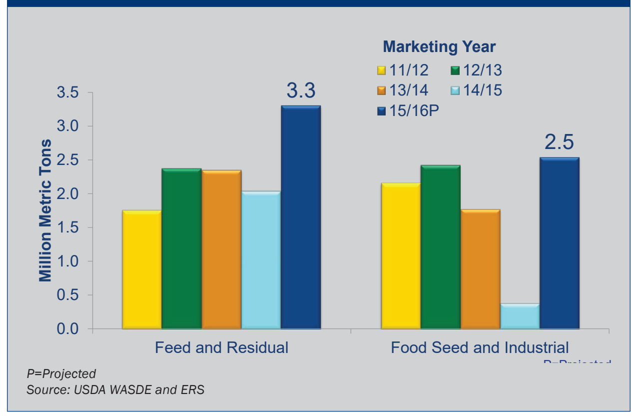
			Difference		Relative % Change*	
State	**2014**	**2015P**	**MMT**	**Percent**	**Acres**	**Yield**
Arkansas	0.4	1.1	0.7	169%		
Colorado	0.2	0.4	0.1	67%		
Kansas	5.1	7.0	2.0	39%		
Louisiana	0.2	0.1	(0.1)	-40%		
Mississippi	0.2	0.3	0.0	19%		
Missouri	0.2	0.4	0.2	88%		
Nebraska	0.3	0.6	0.3	94%		
Oklahoma	0.4	0.5	0.1	24%		
Texas	3.5	4.0	0.5	14%		
Total U.S.	11.0	15.1	4.1	37%		

**Green indicates 2015 is higher than 2014 and red indicates 2015 is lower than 2014; bar height indicates the relative amount.*
P=Projected
Source: USDA NASS

B. U.S. Sorghum Use and Ending Stocks

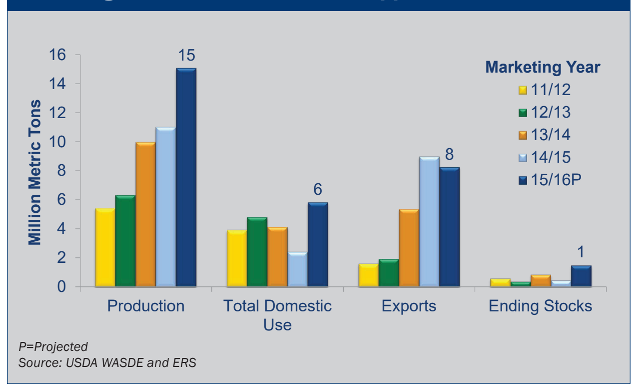
- Beginning in the 2013/2014 marketing year (MY13/14), Chinese imports of U.S. sorghum increased rapidly. As a result of Chinese demand, the U.S. exported approximately 9.0 mmt (352.9 mil bu) of sorghum in MY14/15. This was the highest value for total exports in a single marketing year on record and represented more than 80% of the total U.S. sorghum crop. This demand created price premiums on corn in many parts of the United States, and led to reduced domestic consumption of sorghum for feed and ethanol uses.

U.S. Sorghum Use



- The amount of sorghum used for food, seed and industrial purposes in MY14/15 was much lower relative to MY11/12, MY12/13 and MY13/14, largely due to sorghum's decreased use in ethanol production.

U.S. Sorghum Production and Disappearance



- Despite the spike in export demand for U.S. sorghum and the 2011 crop being the smallest crop in more than 50 years, domestic consumption of sorghum for feed and residual uses remained fairly constant over the past four completed marketing years.

- The smaller 2012 corn crop, due not only to the drought, but also to sorghum's substitutability with corn, drew the MY12/13 sorghum ending stocks to their lowest level in 50 years. While a large crop in MY13/14 helped rebuild ending stocks, the spike in export demand for U.S. sorghum, peaking in MY14/15, again drew ending stocks down to the third-lowest level in the past 50 years.

C. Outlook

1. U.S. Outlook

- With the most harvested hectares in more than a decade and the highest average yield on record, the 2015 U.S. sorghum crop is projected to be more than 37% larger than the previous year's crop. Due to slightly lower exports projected in MY15/16 relative to MY14/15, the domestic use of sorghum in MY15/16 is projected to be higher than any of the previous five completed marketing years.
- Sorghum use for food, seed and industrial (FSI) purposes is expected to rebound in MY15/16 compared to MY14/15, largely due to sorghum's increased expected use in ethanol production.
- Domestic sorghum use for feed and residual use is also expected to increase in MY15/16 compared to MY14/15. Feed demand for sorghum is expected to be supported by its price relative to corn and the practice of feeding livestock longer.
- U.S. sorghum exports during MY15/16 are projected to be about 7.9% lower than last year. If realized, this would result in the second highest level of exports since 1980.
- MY15/16 sorghum ending stocks are projected to be more than three times as high as the previous marketing year, primarily due to the large sorghum crop and slightly less export demand.

2. International Outlook

Global Supply

- Global sorghum production during MY15/16 is expected to be slightly higher than last year's production. This is due to larger crops in both the United States and Mexico, which are the top two sorghum-producing countries in the world.
- In addition to slightly lower U.S. exports, total non-U.S. exports are expected to be lower in MY15/16 than in MY14/15.
- Decreased exports are also expected from Australia, which is a key non-U.S. exporting country along with Argentina.

Global Demand

- Global sorghum use is expected to increase slightly in MY15/16 from MY14/15.
- The top three sorghum-consuming countries over the past two marketing years are China, Mexico, and Nigeria. In addition to slightly higher U.S. use, sorghum use is anticipated to be higher in MY15/16 in Mexico and Australia, and lower in China and Nigeria compared to MY14/15.
- Year-over-year imports are expected to decrease globally in MY15/16, with China responsible for the vast majority of the change.

VIII. U.S. SORGHUM PRODUCTION, USAGE AND OUTLOOK (continued)

U.S. SORGHUM SUPPLY AND USAGE SUMMARY BY MARKETING YEAR

Metric Units	11/12	12/13	13/14	14/15	15/16P
Acreage (million hectares)					
Planted	2.2	2.5	3.3	2.9	3.5
Harvested	1.6	2.0	2.7	2.6	3.1
Yield (mt/ha)	3.4	3.1	3.7	4.2	4.9
Supply (million metric tons)					
Beginning stocks	0.7	0.6	0.4	0.9	0.5
Production	5.4	6.3	10.0	11.0	15.1
Imports	0.0	0.2	0.0	0.0	0.0
Total Supply	**6.1**	**7.1**	**10.4**	**11.9**	**15.6**
Usage (million metric tons)					
Food, seed, and industrial use	2.2	2.4	1.8	0.4	2.5
Feed and residual	1.8	2.4	2.4	2.0	3.3
Exports	1.6	1.9	5.4	9.0	8.3
Total Use	**5.5**	**6.7**	**9.5**	**11.4**	**14.1**
Ending Stocks	0.6	0.4	0.9	0.5	1.5
Average Farm Price ($/mt*)	235.89	249.12	168.43	158.73	125.98-149.60

English Units	11/12	12/13	13/14	14/15	15/16P
Acreage (million acres)					
Planted	5.5	6.3	8.1	7.1	8.7
Harvested	3.9	5.0	6.6	6.4	7.6
Yield (bu/ac)	54.0	49.6	59.6	67.6	77.7
Supply (million bushels)					
Beginning stocks	27	23	15	34	18
Production	213	248	392	433	594
Imports	0	10	0	0	2
Total Supply	**241**	**280**	**408**	**467**	**614**
Usage (million bushels)					
Food, seed, and industrial use	85	95	70	15	100
Feed and residual	69	93	93	80	130
Exports	63	76	211	353	325
Total Use	**218**	**265**	**374**	**449**	**555**
Ending Stocks	23	15	34	18	59
Average Farm Price ($/bu*)	5.99	6.33	4.28	4.03	3.20-3.80

P-Projected
** Farm prices are weighted averages based on volume of farm shipment.*
Average farm price for 15/16P based on WASDE December projected price.

Source: USDA WASDE and ERS

IX. HARVEST SURVEY AND STATISTICAL ANALYSIS METHODS

A. Overview

The key points for the survey design and sampling and statistical analysis for this *2015/2016 Harvest Survey* are as follows:

- The harvest samples were proportionately stratified according to Agricultural Statistical District (ASD) across nine key sorghum-producing states, which represented more than 98% of U.S. sorghum exports. Additionally, the samples were classified according to two Harvest Areas – Early Harvest and Late Harvest.
- A total of 200 harvest samples collected from the nine states were targeted to achieve a maximum ± 10% relative margin of error (Relative ME) at the 95% confidence level for the grade factors.
- There were a total of 207 unblended sorghum harvest samples tested. These samples, received from local elevators, were pulled from inbound farm-originated trucks from August 28, 2015 through January 5, 2016.
- A proportionate stratified sampling technique was used for the mycotoxin testing across the ASDs in the nine states surveyed for the other quality factors. This sampling resulted in 58 harvest 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. Harvest Aggregate and each of the two Harvest Areas.
- To evaluate the statistical validity of the harvest samples, the Relative ME was calculated for each of the quality attributes at the U.S. Harvest Aggregate and the Harvest Areas. The Relative ME for the quality factor results was less than ± 10%, except for three attributes for the U.S. Harvest Aggregate and the Early Harvest Area: BNFM, foreign material, and total damage. While the lower level of precision for these quality factors is suboptimal, these levels of Relative ME do not invalidate the estimates.

Agricultural Statistical Districts (ASDs)

B. Survey Design and Sampling

1. Survey Design

For this *2015/2016 Harvest Survey*, the target population was commodity sorghum from the nine key U.S. sorghum-producing states representing more than 98% of U.S. sorghum exports. A ***proportionate, stratified, random sampling*** technique was applied to ensure a sound statistical sampling of the U.S. sorghum crop at the first stage of the marketing 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 sorghum produced in areas likely to export sorghum to foreign markets. The U.S. Department of Agriculture (USDA) divides each state into several ASDs and estimates sorghum production for each ASD. The USDA sorghum production data, accompanied by USDA sorghum consumption data and foreign export estimates, were used to define the survey population in nine key sorghum-producing states representing more than 98% of U.S. sorghum exports. The ASDs were the subpopulations or strata used for this sorghum quality survey. From those data, the Council calculated each ASD's proportion of the total U.S. foreign exports to determine the ***sampling proportion*** (the percent of total harvest samples per ASD) and ultimately, the number of sorghum harvest samples to be collected from each ASD. The number of samples collected for the *2015/2016 Harvest Survey* differed from ASD to ASD because of the different shares of estimated foreign export levels.

The ***number of harvest samples collected was established*** so the Council could estimate the true averages of the various quality factors with a specific level of precision. The level of precision chosen for the *2015/2016 Harvest Survey* was a Relative ME no greater than ± 10%, estimated with a 95% level of confidence. A Relative ME of ± 10% is a reasonable target for biological data such as these sorghum quality factors.

To determine the number of harvest samples for the targeted Relative ME, ideally the population variance (i.e., the variability of the quality factor in the sorghum 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 harvest samples required to estimate the true mean within a given confidence level. 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.

When population variances are not known, variance estimates from similar data sets are used. Although a reliable source of chemical composition and physical factor data was not available, variances and Relative MEs for the grade factors were calculated using USDA's Grain Inspection, Packers and Stockyards Administration (GIPSA) Farm Gate Studies from 2007 through 2010, and were used as proxies. The variances and the estimated number of harvest samples required for the Relative ME of ± 10% for the grade factors were ultimately determined by examining these studies.

Based on these data, a total sample size of 200 would allow the Council to estimate the true averages of the grade factor characteristics with the desired level of precision for the U.S. Harvest Aggregate, with the exception of total damage.

The same approach of proportionate stratified sampling was used for the mycotoxin testing of the sorghum harvest 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 with a 95% level of confidence, was desired. Testing at least 50 harvest samples (25% of the 200 targeted harvest samples) would ensure with 95% confidence that the percent of tested harvest samples with aflatoxin results below the U.S. Food and Drug Administration (FDA) action level of 20 parts per billion (ppb) would have a Relative ME of less than or equal to ± 10%. It was also estimated that the percent of tested harvest samples with DON results below the FDA advisory level of 5 parts per million (ppm) would have a Relative ME of less than or equal to ± 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 total number of targeted harvest samples (200) and at least one sample from each ASD, the targeted number of harvest samples to test for mycotoxins was 58 samples.

2. Sampling

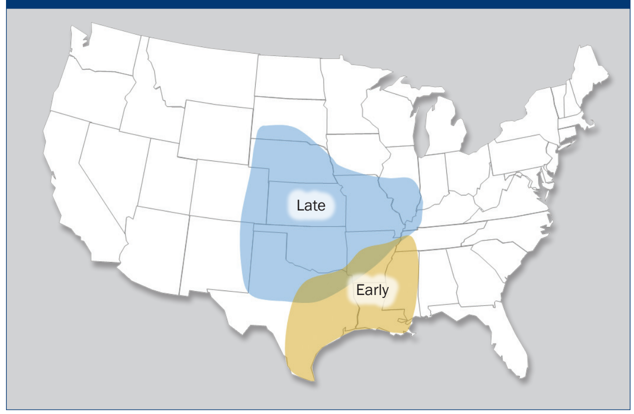
The ***random selection*** process was implemented by soliciting local grain elevators in the nine states by email and phone. Postage-paid sample kits were mailed to elevators agreeing to provide the 2500-gram sorghum samples requested. Samples were collected from the elevators when at least 30% of the sorghum in their area had been harvested. The 30% harvest threshold was established to avoid receiving old-crop sorghum 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 seven samples from each physical location was collected, but nearly 90% of the participating elevators submitted four or fewer samples. A total of 207 unblended sorghum samples pulled from inbound farm-originated trucks were received from local elevators from August 28, 2015 through January 5, 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. Harvest Aggregate and also by two groups. The groups, which harvest sorghum in differing time periods, were labeled as Harvest Areas:

- The Early Harvest Area, which consists of areas that typically harvest sorghum from the beginning of July through the end of September; and
- The Late Harvest Area, which consists of areas that typically harvest sorghum from the beginning of September through the end of November or later.

Harvested Area



In analyzing the harvest sample test results, the Council followed 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. Harvest Aggregate, weighted averages and standard deviations were calculated for the Harvest Areas. First, each sampled ASD was categorized by Harvest Area, based on historical USDA state-level harvest progress data, with each ASD exclusively belonging to one Harvest Area. Second, each ASD was weighted by its estimated proportion of foreign exports. The Harvest Area and U.S. Harvest Aggregate statistics were calculated using these weights.

The Relative ME was calculated for each of the quality factors for the U.S. Harvest Aggregate and for each of the Harvest Areas. The Relative ME for the quality factor results was less than ± 10%, except for total damage for the U.S. Harvest Aggregate and Early Harvest Area, and for foreign material and BNFM for the Early Harvest Area. The Relative ME for total damage, foreign material, and BNFM are shown in the table to the right.

	Relative ME		
	BNFM	Foreign Material	Total Damage
U.S. Aggregate			29%
Early Harvest Area	12%	15%	58%

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

X. EXPORT SURVEY AND STATISTICAL ANALYSIS METHODS

A. Overview

The key points for the survey design and sampling and statistical analysis for this *2015/2016 Export Cargo Survey* are as follows:

- Samples were proportionately stratified according to Export Outlet (EO) – Texas and NOLA.
- To achieve a maximum ± 10% relative margin of error (Relative ME) for the U.S. Export Aggregate level and to ensure proportional sampling from each EO, the targeted number of total samples was 167 samples, with 132 to be collected from Texas and 35 to be collected from NOLA.
- Samples were provided by the U.S. Department of Agriculture's (USDA) Federal Grain Inspection Service (FGIS) field offices at ports in the respective EOs.
- Export inspections of shipments generated 136 samples from the Texas EO and 46 samples from the NOLA EO. Since the number of samples collected in each EO was in excess of the targeted number of samples, the U.S. Export Aggregate averages for the quality factors were weighted according to the targeted proportion by EO.
- To evaluate the statistical validity of the number of samples surveyed, the Relative ME was calculated for each of the quality attributes at the U.S. Export Aggregate level. The Relative MEs for the quality factor results were all less than ± 10%.

B. Survey Design and Sampling

1. Survey Design

For this *Export Cargo Survey*, the target population was commodity sorghum from the nine key U.S. sorghum-producing states representing more than 98% of U.S. sorghum exports. A ***proportionate stratified sampling*** technique was used to ensure a sound statistical sampling of U.S. sorghum exports. Two key characteristics define the sampling technique for this report: the ***stratification*** of the population to be sampled and the ***sampling proportion*** per subpopulation or stratum.

Agricultural Statistical Districts (ASDs)

Stratification involves dividing the survey population of interest into subpopulations called strata. For the *Export Cargo Survey*, the key sorghum-exporting areas in the United States are divided into two geographical groupings, which we refer to as EOs. These EOs are identified by the two major pathways to export markets:

1. The Texas EO includes export terminals along the Texas Gulf Coast, primarily League City (Houston Area) and Corpus Christi; and
2. The NOLA EO comprises the export terminals near the Mississippi River Delta.

To determine the sampling proportion of each EO, the Council used historical and projected data from USDA's National Agricultural Statistics Service (NASS), World Agricultural Supply and Demand Estimates (WASDE), and Export Grain Information Service (EGIS), along with private sources, to estimate the proportion of 2015/2016 sorghum exports from each EO. The sampling proportion (each EO's proportionate share of the total estimated foreign exports) ultimately determined the number of sorghum samples to be collected from each EO. The specified sampling proportion for each EO are as follows: NOLA EO – 21%; and Texas EO – 79%.

The number of samples collected from each EO was established in order for the Council to estimate the true averages of the various quality factors with a specific level of precision. The level of precision chosen for the Export Cargo Survey was a Relative ME of no greater than ± 10%, which is a reasonable target for biological data such as these sorghum quality factors.

To determine the number of samples for the targeted Relative ME, ideally the population variance (i.e., variability of the quality factor in the sorghum exports) for each of the quality factors should be used. The more variation among the levels or values of a quality factor, the more samples required to estimate the true mean within a given confidence level. 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.

When population variances are not known, variance estimates from similar data sets are used. Although a reliable source of chemical composition and physical factor data was not available, variances and Relative MEs for the grade factors were calculated using the EGIS sorghum export data, and were used as proxies. Based on these data, a total sample size of 167 would allow the Council to estimate the true averages of the grade factor characteristics with the desired level of precision for the U.S. Export Aggregate. Applying the sampling proportions previously defined to the total of 167 samples resulted in the following number of targeted samples from each EO: NOLA EO – 35 samples; and Texas EO – 132 samples.

2. Sampling

The sampling was administered by FGIS as part of their inspection services. At the time of this survey's approval in September 2015, new crop sorghum was already being loaded at export points. Therefore, it was decided to start the sampling period as soon as possible. FGIS sent instruction letters to the Texas and NOLA field offices, and the sampling period began the first week of September. The FGIS field office in League City, Texas was responsible for overseeing sample collection in the Texas EO, and the FGIS field office in New Orleans, Louisiana was responsible for the oversight of sample collection in the NOLA EO.

Representative sublot samples from the ports in Texas and NOLA were collected as ships were loaded. Samples for grading are obtained by a diverter sampling device approved by FGIS. The diverter sampler "cuts" (or diverts) a representative portion at periodic intervals from a moving stream of sorghum. A cut occurs every few seconds, or about every 500 bushels (about 12.7 metric tons), as the grain is being assembled for export. The frequency is regulated by an electric timer controlled by official inspection personnel, who regularly ensure that the mechanical sampler is functioning properly.

While the sampling process is continuous throughout loading, a shipment or "lot" of sorghum is divided into "sublots" for the purpose of determining uniformity of quality. Sublot size is based on the hourly loading rate of the elevator and the capacity of the vessel being loaded. Sublot sizes range from 35,000 to 75,000 bushels. All sublot samples are inspected to ensure the entire shipment is uniform in quality.

The sampling frequency for each EO was identical: sublots with identification numbers ending in 0, 3, 5, 7, and 9 from each lot were sampled. Since quantitative aflatoxin testing is not required for exported sorghum shipments, the survey's sampling protocol did not require a sublot to have aflatoxin testing conducted in order to be sampled.

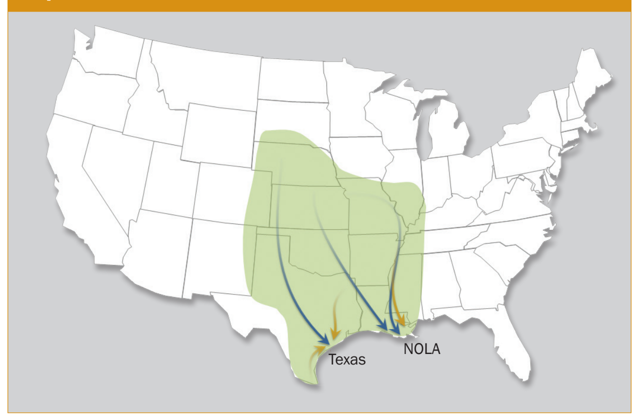
For each sample, the FGIS field staff collected a minimum of 2500 grams. The samples were congregated at the field offices and mailed to the Texas A&M Cereal Quality Laboratory (CQL). Refer to the "Testing Analysis Methods" section for the description of the testing methods employed in the study.

The sampling period ended when the targeted number of samples per EO was reached, which occurred on November 6, 2015 for the Texas EO and on September 18, 2015 for the NOLA EO.

C. Statistical Analysis

The sample test results for the grade factors, moisture, chemical composition, and physical factors were summarized as the U.S. Export Aggregate and also by the two Export Outlets – NOLA and Texas. Contract grades are described in the "Sorghum Export System" section on page 39. For this *2015/2016 Export Cargo Survey*, all of the export samples received were from sublots with contracts that were specified as grade U.S. No. 2 or better, which is the most common grade for which U.S. sorghum export contracts are written.

Export Outlet



The Council followed standard statistical techniques employed for proportionate stratified sampling, including weighted averages and standard deviations, for analyzing the export results. Export inspections of shipments generated 136 samples from the Texas EO and 46 samples from the NOLA EO. Since the number of samples collected in each EO was in excess of the targeted number of samples, the U.S. Export Aggregate averages for the quality factors were weighted using the original sampling proportions.

The Relative ME was calculated for each of the quality factors tested for this study at the U.S. Export Aggregate level, and the Relative ME was less than ± 10% for all the quality attributes measured.

References in the summary tables in the "Export Quality Test Results" section to statistical differences were validated by 2-tailed t-tests at the 95% confidence level. The t-tests were calculated between factors in the *2015/2016 Harvest Survey* and the *2015/2016 Export Cargo Survey*.

XI. TESTING ANALYSIS METHODS

The *2015/2016 Harvest Survey* 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 University, 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 U.S. Department of Agriculture (USDA) 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.

The FGIS field offices provided official grade factor results for the *2015/2016 Export Cargo Survey* samples from their normal inspection and testing procedures for each sublot of sorghum sample collected. The sorghum samples (each about 2500 grams) were sent directly from the FGIS field offices to CQL. The samples were then split into two 1100- to 1250-gram subsamples using a Boerner divider. One subsample was analyzed at CQL for chemical composition and other physical factors using the same methods utilized for the *2015/2016 Harvest Survey* samples. The other subsample was sent to AGE for mycotoxin testing. AGE tested each of the 182 total samples for DON and 135 of the total samples for aflatoxins. While not required, some exported sorghum shipments undergo quantitative aflatoxin testing. In the instances where this testing was conducted by the FGIS field offices, AGE did not conduct aflatoxin testing on the sample and the FGIS-provided aflatoxin results are reported. If the sampled shipment did not undergo quantitative aflatoxin testing, then aflatoxin testing was conducted by AGE. Both mycotoxin tests performed by AGE were conducted using the same methods as the *2015/2016 Harvest Survey*.

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 No. 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 an approximately 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 was 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 of 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 (TKW), Kernel Volume, and Kernel True Density

The 1000-kernel weight (TKW) 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 and automatically calculates the TKW based on the average weight of the 300 individual seeds. The averaged TKW 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 TKW (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, and 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 selects individual kernels, weighs them, and 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.

E. Mycotoxin Testing

Detection of mycotoxins in sorghum 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 sorghum, if present, is highly dependent upon the concentration and distribution of the mycotoxin among kernels in a lot of sorghum, whether a truck load, a storage bin, or a railcar.

The objective of the testing for the *2015/2016 Harvest Survey* is only to report the frequency of occurrences of the mycotoxin in the current crop, but not specific levels of the mycotoxin in sorghum exports. To report the frequency of occurrences of aflatoxins and DON for the harvest samples, AGE performed the mycotoxin testing using FGIS

XI. TESTING ANALYSIS METHODS (continued)

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 2.5-kg survey sample for the mycotoxin analysis. The 1-kg survey sample was ground in a GIPSA-FGIS-approved 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. ROSA AFQ-FAST and DONQ-FAST5 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 70% methanol and 30% distilled water. The extracts were tested using the ROSA lateral flow strips, and the mycotoxins were quantified by the Charm EZ-M system.

The ROSA 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 analytical methods developed for different types of mycotoxins and commodity combinations. The LODs for the ROSA AFQ-FAST and DONQ-FAST5 are 2.0 parts per billion (ppb) aflatoxins for diluted extract, and 0.1 parts per million (ppm) DON for diluted extract.

A letter of performance has been issued by FGIS for the quantification of aflatoxins and DON using the ROSA AFQ-FAST and DONQ-FAST5 kits, respectively.

The mycotoxin tests performed by AGE for the 2015/2016 *Export Cargo Survey* were conducted using the same methods as the *2015/2016 Harvest Survey*. The 47 samples for which aflatoxin testing was performed at the FGIS field offices were tested in accordance with FGIS official procedures. A sample of at least 10 pounds of sorghum was used according to FGIS official procedures. The 10-pound sample was ground using a FGIS-approved grinder. Following the grinding stage, two 500-gram ground portions are removed from the 10-pound comminuted sample using a riffle divider. From one of the 500-gram ground portions, a 50-gram test portion is randomly selected for testing. After adding the proper extraction solvent to the 50-gram test portion, aflatoxin is quantified. The following FGIS-approved quantitative test kits may have been used: VICAM AflaTest™, Romer Labs FluoroQuant Afla or FluoroQuant Afla IAC, Envirologix QuickTox™ for QuickScan Aflatoxin (AQ 109 BG and AQ 209 BG), Neogen Reveal Q+ for Aflatoxin or Veratox® Aflatoxin Quantitative Test, Charm Sciences ROSA® FAST or WET-S5™ Aflatoxin Quantitative Tests, or R-Biopharm RIDASCREEN® FAST Aflatoxin SC test or RIDA QUICK Aflatoxin RQS.

XII. 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

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