



Grain Grading Standards in Feed Manufacturing

Department of Grain Science and Industry

Each year, some low quality grain enters the market channel following a growing season that is characterized by drought, extreme heat during a sensitive stage in crop development, excess moisture, an early frost, plant disease, or other malady. During years when vast geographical areas are affected by unfavorable growing conditions, a large quantity of low-grade grain may be available for purchase and feeding. In such markets, livestock producers may realize additional profits when utilizing low-grade grain that has been discounted.

The processing performance and feeding value may be reduced in grain that experienced significant quality deterioration due to unfavorable growing conditions. The purpose of this bulletin is to explain the different factors used to assign a grain grade and how these factors may influence the processing performance and feeding value of the low-grade grain.

Grain Grades and Standards

A set of standards established by the United States Department of Agriculture (USDA), known as the Grain Grading Standards (USDA 1995), serve as a general guideline for characterizing physical grain quality. This system was developed in 1916 to enable grain merchants to trade grain using consistent, measurable quality criteria. Since 1916, numerous changes in the grading standards have occurred to reflect changes in technology (the ability to measure quality) and customer demands.

Grain quality measurements are categorized as nongrade determining factors, grade determining factors, and special grades. Grade tables included in the back of this bulletin list the minimum and maximum criteria for each grading factor and the definition of each special grade.

Nongrade determining factors include moisture and possibly dockage (depending on the grain). These factors are measured using approved testing equipment following official procedures. The results of these tests are included on the Grade Certificate; however, the information is not used to assign a grade. For example, an individual purchasing U.S. Number 2 corn may receive grain with any moisture content (e.g. 10 to 20%).

Grade determining factors include test weight, damaged kernels, foreign material, broken kernels, odor, and heating. These factors are used to assign a numerical grade. Grades are assigned based on the lowest factor. For example, if a corn sample has a test weight of 56 pounds per bushel (minimum criteria for U.S. Number 1) and heat damage of 1 percent (maximum criteria for U.S. Number 4), the grade assigned to the grain would be U.S. Number 4. The presence of musty, sour, or commercially objectionable foreign odor or the presence of heating causes the grain to be assigned the title **Sample Grade**. Sample grade is the lowest possible category in the grading system.

Special grades (depending on the grain) include infested, ergoty, garlicky, and smutty. These words are added to the grade designation but do not determine the numerical grade. For example, sorghum that meets or exceeds grading factors for U.S. Number 1 and contains 20 or more smut balls in a 100 gram portion would be assigned the following grade, U.S. Number 1 Sorghum, Smutty.

These characteristics provide some insight into the processing value, past or future problems related to storage, and, to a lesser extent, the nutritional value of grain. The Federal Grain Inspection Service (FGIS) and licensed inspection agencies and firms also offer informational services and tests. Quality

characteristics measured by these agencies (upon request) include mycotoxins, protein and oil content, and stress crack in corn.

Nongrade Determining Factors

Moisture content was dropped as a grade determining factor in 1988 as an outgrowth of the Grain Standards Act of 1986. Because moisture level in grain is extremely important, it is measured and reported on all grade certificates. However, customers must specify the maximum (and in some cases minimum) moisture content of grain they intend to purchase since it is no longer used to assign a grade.

Moisture content is important to a cattle feeder for several reasons. First, and perhaps foremost, moisture content provides an indication of how much dry matter (feeding value) is contained in the grain. A reduction in moisture content in grain results in a weight reduction referred to as shrink. This moisture: weight relationship is expressed by the following equation:

$$\% \text{ Weight Change (shrink)} = \frac{\text{Mo} - \text{Mf}}{100 - \text{Mf}} \times 100$$

Mo = original or initial moisture content (%)
Mf = final moisture content (%)

The percent weight change or moisture shrink when corn dries from 17 percent to 14 percent can be calculated as follows:

$$\% \text{ Weight Change (shrink)} = \frac{17 - 14}{100 - 14} \times 100 = 3.49$$

A shrink factor can be derived by dividing moisture shrink by the percent change in moisture content: (e.g. $3.49 \div 3 = 1.16$)

Many grain elevators use a fixed moisture shrink factor (e.g. 1.2) when discounting high-moisture grain to a predetermined moisture content.

Moisture content in grain also determines the length of time grain can be stored. High moisture grain is more prone to experience a deterioration in quality due to mold. The relationship between grain moisture content and quality deterioration due to mold is temperature dependent as expressed in Table 1 (Sauer 1988).

The presence of mold can result in reduced grain palatability, feed refusal, and the occurrence of mycotoxins. Further information on mycotoxins, testing procedures, and animal symptoms experiencing mycotoxicosis can be found in *Mycotoxins in Feed Grains and Ingredients*, MF-2061, Kansas State University Cooperative Extension Service.

Grain moisture content has an inverse relationship with test weight. In other words, as moisture content increases, test weight decreases. This relationship is expressed by the following equation (Nelson 1980):

$$D = 701.9 + 1676M - 11,598M^2 + 18,240M^3$$

D = density in kilograms per cubic meter

This method of expressing the relationship between density and mass-moisture of grain is part of the American Society of Agricultural Engineers (ASAE) and American National Standards Institute (ANSI) Standards D241.4 Feb 93. Density expressed in kilograms per cubic meter can be converted to pounds per bushel using the constant 0.0777 as follows: $D \times 0.0777 = \text{pounds per bushel}$.

Table 1. Maximum time (days) for storage of shelled corn at various moisture contents and air temperatures to experience one grade reduction.

Storage air temperature (Fahrenheit)	Corn Moisture Content			
	15%	20%	25%	30%
75	116	12	4	3
70	155	16	5	4
65	207	21	8	5
60	259	27	10	6
55	337	35	13	8
50	466	48	17	10
45	725	75	27	16
40	906	94	34	20
35	1140	118	42	25

Figure 1 presents the relationship between moisture content and test weight derived from the Nelson equation. The six lines represent grains of different test weight (e.g. corn with test weights of 48, 50, 52, 54, 56, 58, and 60 pounds per bushel at 14 percent moisture). Little change in test weight occurs between 10 to 12 percent moisture content, whereas test weight declines almost $\frac{1}{2}$ pound per 1 percent increase in moisture greater than 14 percent.

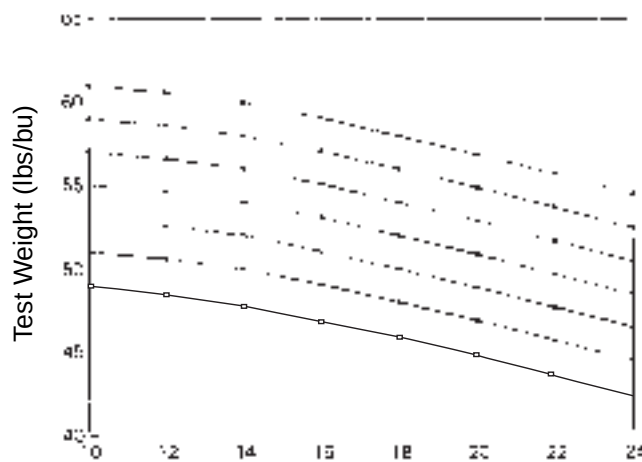


Figure 1. Relationship between test weight and moisture content for corn derived from Nelson's equation.

Dockage in feed grain is measured for barley, rye, sorghum, triticale, and wheat. Dockage is removed prior to measuring test weight for all grains listed above except sorghum. Dockage is defined in the U.S. Wheat Standards as the nonwheat material removed by an approved cleaning device (a similar definition exists for the other grains listed above). The Carter Day dockage tester is the approved cleaning device for official inspection, however, other grain cleaners are available for measuring dockage. In the absence of a mechanized method for removing dockage, hand sieves may be used as describe by the FGIS procedures.

Dockage may possess limited feeding value and hinders airflow through stored grain, which results in uneven cooling and development of hot spots. Dockage exerts a negative influence on handling grain (e.g. slows its flow through the pit and reduces leg capacity) and lowers the test weight measure of grain.

Grade Determining Factors

Test weight is a bulk density measure (weight per given volume) and is reported as pounds per Winchester bushel (bu). While low test weight grain may not translate into reduced feeding value, processing costs may increase dramatically.

Data generated at Kansas State University from 1991 to 1994 for swine indicated that the feeding value of sorghum with a test weight as low as 35 pounds per bushel was only 10 to 12 percent lower than that of 57 pounds per bushel test weight sorghum. This reduction in feeding value of light sorghum is in sharp contrast with the 30 to 50 percent discount in price received by farmers (Traylor et al 1995).

However, when comparing processing performance of high and low test weight sorghum, Kansas State University researchers report that as test weight dropped from 58 pounds per bushel to 39 pounds per bushel, grinding rate was reduced by 45 percent and grinding cost increased over 5 fold from \$0.41 per ton to \$2.33 per ton.

Numerous other studies evaluating the feeding value of low test weight grains on different animal species indicate that there is little or no correlation between test weight and animal performance. Perhaps the only contradiction to this was reported for barley in Idaho. Researchers discovered that, in a cattle finishing study, average daily gain and feed efficiency fell about 1 percent for each pound decrease in test weight (GPE Factsheet 2000).

Foreign material is the nongrain material that remains in a sample after the dockage is removed. In grains and oilseeds such as corn and soybeans, dockage is not measured, thus foreign material takes on a slightly different meaning.

In corn, the foreign material is measured with broken corn and is defined as follows: all matter that passes readily through a $\frac{1}{64}$ inch round-hole sieve and all matter other than corn that remains in the sieved sample.

Broken corn and foreign material (BCFM) generally elevates the fiber content while protein and nitrogen free extract (NFE) content is usually comparable to clean grain. Although BCFM provides limited information pertaining to the nutritional value of corn, this grading factor does indicate possible handling, storage, and processing problems. Broken kernels are more susceptible to mold invasion and insect infestation during storage. BCFM limit air flow in storage and contributes to feedbunk fines.

Damaged kernels can include evidence of heat damage, germ damage, sprouting, mold, and insect damage.

Heat damage is designated separately in all grading charts and represents the tightest standard for kernel damage. Kernels experiencing heat damage tend to possess limited nutritional value. Heat damage results from storing grain that possessed too high of a field moisture content, from moisture migration due to convective air currents in the bin, or from localized infestations of stored grain insects that produce heat. Any of these conditions creates an environment that favors mold growth and heating from respiration. As a consequence, the endosperm turns dark brown or black.

Drier damage may result in kernels that are puffed or swollen and materially discolored by the drier heat. This form of damage, if of similar intensity as heat damage, may be designated as such. Grain damage caused by a drier that appears less severe than heat damage is designated as damaged by heat. This form of damage is included in the total damage category.

Germ damage is caused by heat of respiration, however, only the embryo (germ) is damaged. This form of damage in corn would result in off-color oil. Since the severity of damage is less than heat damage, there is little or no effect on the nutritional value or feed processing characteristics. Germ damage is included in the total damage category.

Sprout damage occurs in the field when physiologically mature grain is exposed to rain and high humidity and may occur in storage in response to conditions described under heat damage. Sprouting is caused by an activation of enzymes that convert the long-chain starch molecules in the endosperm into smaller carbohydrates and simple sugars, which serve as food to the young plant. Storage proteins also are split into smaller compounds during sprouting. The feeding value of sprout damaged grain is not affected. The occurrence of sprout damaged grain may indicate other problems that a feeder should be concerned about, specifically, the presence of molds and mycotoxins.

Mold damage may occur during the growing season or storage. Grain stored under high moisture or temperature conditions is more prone to mold problems and the development of mycotoxins. Mycotoxins are toxic metabolites produced by mold, which can cause severe animal health problems and death.

Scab damage in wheat results from field infection by *Fusarium* species during flowering and kernel development. Kernels that are scab damaged have a dull, lifeless, chalky appearance and usually contain

mold in the germ or in the crease. Scabby wheat may contain deoxynivalenol (DON), also called vomitoxin. Symptoms produced by DON-contaminated wheat include feed refusal, digestive disorders, diarrhea, and possibly death.

The presence of **odor** (designated as musty, sour, or commercially objectionable foreign) or **heating** causes grain to be designated as sample grade (the lowest designation in the grain grading system). All of these odors are indicative of a grain storage/transportation problem. Musty odor indicates the presence of certain grain boring insects or mold, and commercially objectionable foreign odor may result from petroleum products or excessive fumigant use. For example, sour odor may be an indication of insect infestation or fermenting/moldy grain. Rodent excrement also may cause an off-odor. Rodents, cats, and birds can potentially spread disease through feces, urine, and body parts such as feathers or hair. Feeders should thoroughly inspect grain for the cause of the odor before accepting delivery or using this grain.

Special Grades

Infested grain, while possibly possessing satisfactory feeding value and processing performance can lead to economic losses. Many grain elevator managers discount grain \$0.05 per bushel to cover the cost of fumigating infested grain. Feeders should not knowingly receive infested grain without a discount and fumigation strategy in place. The use of fumigants requires personnel possess a special applicators permit and proper equipment including air quality monitoring instrumentation and personnel protective equipment.

Ergot may occur in cultivated grasses including wheat, triticale, barley, oats, and rye. A purple-black fungal mass (sclerotium) contains alkaloids which can cause gangrene or convulsions. Ergot grain should not be fed to livestock without a preplanned strategy to mitigate problems. Such a problem should include quantification of the amount of ergot and a method for removing or reducing the amount of ergot below the level specified in the respective grain grading standards.

Smutty grain, while potentially not a threat to the nutritional value or animal health, may produce an off odor. Most smut problems can be controlled during production through the use of a fungicide seed treatment.

Summary

Although the U.S. Grain Grading Standards were first developed to facilitate grain merchandising through the use of uniform tests and terms, grain grades also provide valuable information to the end-user regarding feed processing performance and feeding value of low-grade grain. Occasionally, the opportunity exists to purchase low-grade grain at a substantial discount. Feeders must factor into their purchasing decision the cause of grain quality deterioration, increased cost of processing, and potential health risks to the animal. A thorough understanding of the Grain Grading Standards will enable feeders to make wise choices regarding the purchase and use of low-grade grain.

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Wheat

Grades and Grade Requirements

Grading Factors	Grades U.S. Nos.				
	1	2	3	4	5
Minimum pound limits of:					
Test Weight					
Hard Red Spring wheat or White Club wheat (lbs/bu)	58.0	57.0	55.0	53.0	50.0
All other classes and subclasses (lbs/bu)	60.0	58.0	56.0	54.0	51.0
Maximum percent limits of:					
Defects					
Damaged kernels					
Heat (part of total)	0.2	0.2	0.5	1.0	3.0
Total	2.0	4.0	7.0	10.0	15.0
Foreign material	0.4	0.7	1.3	3.0	5.0
Shrunken and broken kernels	3.0	5.0	8.0	12.0	20.0
Total ¹	3.0	5.0	8.0	12.0	20.0
Wheat of other classes²					
Contrasting classes	1.0	2.0	3.0	10.0	10.0
Total ³	3.0	5.0	10.0	10.0	10.0
Stones	0.1	0.1	0.1	0.1	0.1
Maximum count limits of:					
Other material					
Animal filth	1	1	1	1	1
Castor beans	1	1	1	1	1
Crotalaria seeds	2	2	2	2	2
Glass	0	0	0	0	0
Stones	3	3	3	3	3
Unknown foreign substance	3	3	3	3	3
Total ⁴	4	4	4	4	4
Insect-damaged kernels in 100 grams	31	31	31	31	31

U.S. Sample grade Wheat that:

- (a) Does not meet the requirements for U.S. Nos. 1, 2, 3, 4, or 5; or
- (b) Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
- (c) Is heating or of distinctly low quality

¹Includes damaged kernels (total), foreign material, and shrunken and broken kernels.

²Unclassed wheat of any grade may contain not more than 10.0 percent of wheat of other classes.

³Includes contrasting classes.

⁴Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance.

Special Grades and Special Grade Requirements

- (a) **Ergoty wheat.** Wheat that contains more than 0.05 percent of ergot.
- (b) **Garlicky wheat.** Wheat that contains in a 1,000-gram portion more than two green garlic bulblets or an equivalent quantity of dry or partly dry bulblets.
- (c) **Infested Wheat.** Wheat that is infested with two or more live insects injurious to stored grain.
- (d) **Light smutty wheat.** Wheat that has an unmistakable odor of smut, or which contains, in a 250 gram portion, smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to five smut balls, but not in excess of a quantity equal to 30 smut balls of average size.
- (e) **Smutty wheat.** Wheat that contains in a 250-gram portion smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to 30 smut balls of average size.
- (f) **Treated wheat.** Wheat that has been scoured, limed, washed, sulfured, or treated in such a manner that the true quality is not reflected by either the numerical grades or the U.S. Sample grade designation alone.

Sorghum

Grades and Grade Requirements

Grading Factors	Grades U.S. Nos. ¹			
	1	2	3	4
Minimum pound limits of:				
Test Weight lbs/bu	57.0	55.0	53.0	51.0
Maximum percent limits of:				
Damaged kernels				
Heat (part of total)	0.2	0.5	1.0	3.0
Total	2.0	5.0	10.0	15.0
Broken kernels and foreign material				
Foreign material (part of total)	1.5	2.5	3.5	4.5
Total	4.0	7.0	10.0	13.0
Maximum count limits of:				
Other material				
Animal filth	9	9	9	9
Castor beans	1	1	1	1
Crotalaria seeds	2	2	2	2
Glass	1	1	1	1
Stones ²	7	7	7	7
Unknown foreign substance	3	3	3	3
Cocklebur	7	7	7	7

U.S. Sample grade Sorghum that:

- (a) Does not meet the requirements for U.S. Nos. 1, 2, 3, or 4; or
- (b) Has a musty, sour, or commercially objectionable foreign odor (except smut); or
- (c) Is badly weathered, heating, or distinctly low quality.

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

²Aggregate weight of stones also must exceed 0.2 percent of the sample weight.

Special Grades and Special Grade Requirements

- (a) **Smutty Sorghum.** Sorghum that has kernels covered with smut spores to give a smutty appearance in mass, or that contains 20 or more smut balls in 100 grams of sorghum.
- (b) **Infested Sorghum.** Sorghum that is infested with two or more weevils, one live weevil and five other live insects injurious to stored grain or 10 live insects injurious to stored grain.

Corn Grades and Grade Requirements

Grading Factors	Grades U.S. Nos.				
	1	2	3	4	5
Test Weight					
Minimum per bushel (pounds)	56.0	54.0	52.0	49.0	46.0
Maximum percent limits of:					
Damaged kernels					
Heat	0.1	0.2	0.5	1.0	3.0
Total	3.0	5.0	7.0	10.0	15.0
Broken corn and foreign material	2.0	3.0	4.0	5.0	7.0

U.S. Sample grade Corn that:

- (a) Does not meet the requirements for U.S. Nos. 1, 2, 3, 4, or 5; or
- (b) Contains eight or more stones which have an aggregate weight in excess of 0.20 percent of the sample weight, 2 or more pieces of glass, three or more crotalaria seeds (*Crotalaria* spp.), two or more castor beans (*Ricinus communis* L.), four or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), eight or more cockleburrs (*Xanthium* spp.) or similar seeds singly or in combination, or animal filth in excess of 0.20 percent in 1000 grams; or
- (c) Has a musty, sour, or commercially objectionable foreign odor; or
- (c) Is heating or of distinctly low quality.

Special Grades and Special Grade Requirements

- (a) **Flint corn.** Corn that consists of 95 percent or more of flint corn.
- (b) **Flint and dent corn.** Corn that consists of a mixture of flint and dent corn containing more than 5.0 percent but less than 95 percent of flint corn.
- (c) **Infested Corn.** Corn that is infested with two or more live weevils, one live weevil and five other live insects injurious to stored grain or 10 live insects injurious to stored grain.
- (d) **Waxy corn.** Corn that consists of 95 percent or more waxy corn according to procedures prescribed in FGIS instructions.

Six-rowed Barley, Two-rowed Barley and Barley Grades and Grade Requirements

Grade	Minimum limits of		Maximum limits of				
	Test weight per bushel (pounds)	Sound barley (percent)	Damaged kernels ¹ (percent)	Heat-damaged kernels (percent)	Foreign material (percent)	Broken kernels (percent)	Thin Barley* (percent)
U.S.No. 1	47.0	97.0	2.0	0.2	1.0	4.0	10.0
U.S.No. 2	45.0	94.0	4.0	0.3	2.0	8.0	15.0
U.S.No. 3	43.0	90.0	6.0	0.5	3.0	12.0	25.0
U.S.No. 4 ²	40.0	85.0	8.0	1.0	4.0	18.0	35.0
U.S.No. 5	36.0	75.0	10.0	3.0	5.0	28.0	75.0

U.S. Sample grade Barley that:

- Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or
- Contains eight or more stones or any number of stones which have an aggregate weight in excess of 0.2 percent of the sample weight, two or more pieces of glass, three or more crotalaria seeds (*Crotalaria* spp.), two or more castor beans (*Ricinus communis* L.), four or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), eight or more cocklebur (*Xanthium* spp.) or similar seeds singly or in combination, 10 or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1¹/₈ to 1¹/₄ quarts of barley; or
- Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
- Is heating or otherwise of distinctly low quality.

¹Includes heat-damaged kernels. Injured-by-frost kernels and injured-by-mold kernels are not considered damaged kernels.

²Barley that is badly stained or materially weathered shall be graded not higher than U.S. No. 4.

*Use the 5/64 x 3/4 slotted-hole sieve for the class Six-rowed barley and the class Barley. Use the 5.5/64 x 3/4 slottedhole sieve for the class Two-rowed barley.

Special Grades and Special Grade Requirements

- Blighted barley.** Barley that contains more than 4.0 percent of fungus-damaged and/or mold-damaged kernels.
- Ergoty barley.** Barley that contains more than 0.10 percent ergoty.
- Garlicky barley.** Barley that contains three or more green garlic bulblets or an equivalent quantity of dry or partly dry bulblets in 500 grams of barley.
- Infested barley.** Barley that is infested with two or more live weevils, one live weevil and five other live insects injurious to stored grain or 10 live insects injurious to stored grain.
- Smutty barley.** Barley that has kernels covered with smut spores to give a smutty appearance in mass or which contains more than 0.20 percent smut balls.

Oats

Grades and Grade Requirements

Grade	Minimum limits		Maximum limits		
	Test weight per bushel (pounds)	Sound oats (percent)	Heat-damaged kernels (percent)	Foreign material (percent)	Wild oats (percent)
U.S. No. 1	36.0	97.0	0.1	2.0	2.0
U.S. No. 2	33.0	94.0	0.3	3.0	3.0
U.S. No. 3 ¹	30.0	90.0	1.0	4.0	5.0
U.S. No. 4 ²	27.0	80.0	3.0	5.0	10.0

U.S. Sample grade Oats which:

- (a) Do not meet the requirements for the grades U.S. Nos. 1, 2, 3, or 4; or
- (b) Contain eight or more stones which have an aggregate weight in excess of 0.2 percent of the sample weight, two or more pieces of glass, three or more crotalaria seeds (*Crotalaria* spp.), two or more castor beans (*Ricinus communis* L.), four or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), eight or more cocklebur (*Xanthium* spp.) or similar seeds singly or in combination, 10 or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1¹/₈ to 1¹/₄ quarts of oats; or
- (c) Have a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
- (d) Are heating or otherwise of distinctly low quality.

¹Oats that are slightly weathered shall be graded not higher than U.S. No. 3.

²Oats that are badly stained or materially weathered shall be graded not higher than U.S. No. 4.

Special Grades and Special Grade Requirements

- (a) **Bleached oats.** Oats that in whole or in part have been treated with sulfurous acid or any other bleaching agent.
- (b) **Bright oats.** Oats, except Bleached oats, that are of good natural color.
- (c) **Ergoty oats.** Oats that contain more than 0.10 percent ergot.
- (d) **Extra-heavy oats.** Oats that have a test weight per bushel of 40 pounds or more.
- (e) **Garlicky oats.** Oats that contain four or more green garlic bulblets or an equivalent quantity of dry or partly dry bulblets in 500 grams of oats.
- (f) **Heavy oats.** Oats that have a test weight per bushel of 38 pounds or more but less than 40 pounds.
- (g) **Infested oats.** Oats that are infested with two or more live weevils, one live weevil and five other live insects injurious to stored grain or 10 live insects injurious to stored grain.
- (h) **Smutty oats.** Oats that have kernels covered with smut spores to give a smutty appearance in mass or that contain more than 0.2 percent of smut balls.
- (i) **Thin oats.** Oats that contain more than 20.0 percent of oats and other matter, except fine seeds, that pass through a 0.064 by ³/₈ oblong-hole sieve but remain on top of a ⁵/₆₄ triangular-hole sieve after sieving according to procedures prescribed in FGIS instructions.



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