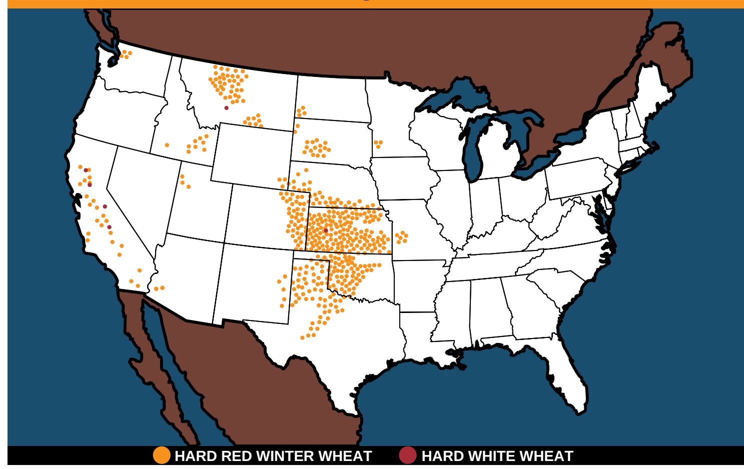
Quality Oriented Marketing *of* HARD WINTER WHEAT

A description of quality evaluation techniques

Hard Winter Wheat Growing Areas in the United States



COOPERATIVE EXTENSION SERVICE
KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS

EVALUATION EQUIPMENT

A Single kernel wheat characterization system

B MCI Kicker laboratory grain cleaner

C Rapid Visco Analyzer

D Rotap kernel size test

E Carter Day dockage tester

F Mixograph recording dough mixer

G Farinograph recording dough mixer

H Quadrumat Senior laboratory flour mill

I Falling Number

J Alveographe physical dough testing equipment

Wheat Kernel Damage

A) WHEAT HEAT DAMAGE kernels and pieces of kernels of wheat damaged by heat and materially discolored to the extent shown.
Whole kernels of wheat must occasionally be cross-sectioned (see Kernel 3) to confirm the entire face of both halves are as dark or darker than shown in Kernels 1 or 2.

B) WHEAT GERM DAMAGE (Sick Wheat–Damaged as result of Respiration) Kernels with germs as dark or darker than the kernel shown are damaged.
Procedure: Kernels should be scraped carefully with a sharp instrument such as a pick to avoid scraping too deeply and destroying the evidence of damage.
Note: Germs with more intense discoloration require less coverage to be considered damage.

C) WHEAT WEEVIL OR INSECT BORED DAMAGE Kernels that have been bored or tunneled by insects are damaged. Illustrated from left to right:
Kernel 1: Kernel that has been tunneled.
Kernels 2 and 3: Kernels that have been bored.

D) WHEAT FROST DAMAGE (Flaked) Kernels that have a slight flaked-off bran coat due to frost.
Note: Evidence of frost must be present. Do not confuse with kernels that have the bran coat rubbed off due to handling.

E) WHEAT SPROUT DAMAGE Kernels with the germ covers broken open due to germination and showing sprouts or from which the sprouts have broken off are damaged. Illustrated from left to right:
Kernel 1: The sprout is broken off leaving part of the germ cover over the socket area.
Kernel 2: The sprout is broken off leaving no germ cover over the socket area.
Note: The starchy area may or may not be discolored.
Kernel 3: The germ cover is broken open with a sprout showing at the bottom.
Kernel 4: The germ cover is broken open with a sprout showing at the top.
Note: Sprouts must be equal to or greater than shown on Kernels 3 and 4.

F) WHEAT BLIGHT, SCAB DAMAGE Scab damage is a result of disease. Kernels that are scab-damaged have a dull, lifeless, chalky appearance and usually contain mold in the germ or in the crease. Kernels meeting any one of the following criteria are damaged. Illustrated from left to right:
Kernel 1: Kernels with the scab appearance as shown and as described above shall be considered damaged without further examination.
Kernel 2: Kernels with the scab appearance as described above and containing mold in the crease equal to or greater than shown.
Kernel 3: Kernels with the scab appearance as described above and containing mold in the germ.
Procedure for Kernel 3: Kernels shall be scraped carefully with the use of a sharp instrument such as a pick to avoid scraping too deeply and destroying the evidence of damage.

Contents

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Quality Oriented Marketing *of* HARD WINTER WHEAT

A description of quality evaluation techniques

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U.S. farmers produce about 2.4 billion bushels of wheat each year. The average annual hard winter wheat production from 1990 to 1994 was 970 million bushels valued at an estimated $3.1 billion (Economic Research Service, 1994). Per capita consumption of flour in the United States has increased to 144 pounds, and in 1994 flour mills produced a record 390 million hundredweight (Milling & Baking News, 1995).

Despite these favorable trends in wheat processing and flour utilization, the production and storage of wheat have become less profitable in recent years. Since 1983 production costs have remained well above the market price of wheat with several years showing more than a dollar per bushel difference. The recent idling of nearly 64 million acres of cropland in government programs (National Grain and Feed Association, 1992) and the reduction of government grain storage has rendered nearly 47 percent of the commercial grain-storage system unused (National Agricultural Statistics Service, 1994).

Declining public and private returns to U.S. wheat producers and concern about the strategic trade position of the United States relative to other wheat exporters, especially Canada, have been major factors in prompting the pursuit of a quality-oriented marketing system as defined in the Grain Quality Acts of 1986 and 1990 (Stiegert, 1995). In these bills Congress mandated the Federal Grain Inspection Service (FGIS) and the Agricultural Research Service (ARS) collaborate in the design and implementation of a quality-based classification and grain-grading system.

The single kernel wheat characterization system, which measures individual kernel weight, size, moisture, and hardness, is the first of these new technologies that will be incorporated into the official grain-inspection system. Scientists throughout the world are involved in developing new technologies that rapidly measure and predict end-use qualities in grain (Smail, 1995).

In spite of research advances pertaining to wheat quality characterization and technology development to predict wheat end-use quality, most farmers and grain handlers treat hard red winter wheat as a commodity. The U.S. farm program encourages production of high-yielding wheat with little regard to processor needs, and the U.S. grain-grading standards encourage blending wheat by commercial grain elevators based on grading factors rather than end-use quality. The ratification of the General Agreement on Trade and Tariffs (GATT) by the U.S. Congress and political pressure to reduce farm subsidies create an environment more conducive to the adoption of a marketing system that rewards the production and segregation of wheat based on end-use quality.

In response to these developments, this bulletin was prepared to help educate producers, grain handlers, and grain merchandisers in technology used to evaluate hard winter wheat quality and to explain the relationship between these measurements and end-use properties. This is important as individuals prepare to participate in opportunities involving value-added marketing of hard winter wheat. The discussion of wheat quality characteristics is divided into three categories: **physical, sanitary,** and **intrinsic quality.** A case study was performed to demonstrate the potential value associated with quality-oriented marketing of hard winter wheat. A glossary of terms pertaining to wheat quality, its measurement, flour types, baking equipment, and dough properties is included at the back of this bulletin.

Physical Quality Characteristics

Most hard winter wheat produced in the United States is marketed using physical quality characteristics outlined in the U.S. Wheat Standards (FGIS, 1993). Dockage and moisture measurements are reported on the official grain certificate as mandatory nongrade determining factors. Quality measurements that determine grade include test weight, kernel damage, shrunken and broken wheat, foreign material (FM) and the presence of wheat from a contrasting class (Table 1).

Dockage is defined in the U.S. Wheat Standards as the nonwheat material removed by an approved cleaning device. The Carter Day dockage tester is the approved cleaning device for official inspection; however, other grain cleaners are available for measuring dockage. These mechanical cleaners remove the nonwheat material (dockage) using aspiration and sieves. In the absence of a mechanized method for removing dockage, hand sieves may be used to remove nonwheat material for the purpose of estimating dockage. Further details on hand sieving and grain grading methods are presented in Appendix 1.

Moisture can be measured indirectly using electrical meters or a near-infrared spectrophotometer (NIR) or by taking a direct moisture measurement such as the oven-dry method. The Motomco 919 electrical meter, which is approved by FGIS for official grain inspection, is accurate within ±0.4 percent for wheat ranging in moisture content between 8 and 16 percent.

Changing the moisture content of wheat changes its weight. This relationship is expressed mathematically using the following equation:

$$\textit{\% Weight Change (or Moisture Shrink)} = \frac{Mo - Mf}{100 - Mf} \times 100$$

Mo = original or initial moisture content (%)

Mf = Final moisture content (%)

The percent weight change or moisture shrink when wheat dries from 14 percent to 12 percent moisture content can be calculated as follows:

$$\textit{\% Weight Change} = \frac{14-12}{100-12} \times 100 = 2.27$$

A **shrink factor** can be derived by dividing moisture shrink by the percent change in moisture content (e.g. 2.27 ÷ 2 = 1.135). Many grain elevators use a fixed moisture shrink factor (e.g. 1.2) when discounting high-moisture grain.

Test weight is a bulk density measure (weight per given volume) and is reported as pounds per Winchester bushel (bu). Test weight provides a rough estimate of flour yield potential in hard winter wheat. The cause of low test weight is important when considering wheat end-use performance. Dockage in a wheat sample reduces test weight; therefore, official test weight measures are performed on dockage-free wheat as specified by the U.S. Wheat Standards (FGIS, 1993). Shriveled kernels caused by disease, drought, and heat stress during kernel development reduce test weight and flour yield. A low test weight caused by kernels swelling after a rain on physiologically mature wheat may not necessarily lower flour yield. Severe weathering, however, may cause a significant deterioration of intrinsic quality.

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):

$$D = 774.4 - 703\,M + 18{,}510\,M^2 - 1489{,}960\,M^3 + 311{,}600\,M^4$$

where: D = density expressed as kg/m^3
M = % moisture wet basis/100.

This method of expressing the relationship between density and mass-moisture of grain (for storage) is part of the American Society of Agricultural Engineers (ASAE) and American National Standards Institute (ANSI) Standards D241.4 Feb93. Density expressed in kilograms per cubic meter can be converted to pounds per bushel using the constant 0.0777 as follows:

$$D \times 0.0777 = \text{lbs/bu}$$

Figure 2 presents the relationship between moisture content and test weight derived from the Nelson equation. The six lines represent grain of different bulk density (e.g. wheat with test weights of 52, 54, 56, 58, 60 and 62 pounds at 14-percent moisture). Little change in test weight occurs between 8 to 12 percent moisture content, whereas test weight declines almost 1 pound per 1 percent increase in moisture greater than 15 percent.

Foreign material (FM) includes all nonwheat material that remains in the dockage-free and shrunken or broken free portion of a sample. Often, the removal of FM requires more machinery than is present in commercial elevators equipped with grain cleaners, which clean grain using aspiration and sieves. Disk separators and gravity tables, which remove nonwheat material based on shape and density, respectively, may be required to clean out the FM from wheat. Both types of cleaning equipment are usually present in flour mills and seed houses. In some cases, it may not be possible to remove the nonwheat material because it so closely resembles wheat in size, shape, and density. Contamination by this type of material may render the wheat unmerchantable for food processing.

Shrunken and broken wheat are those kernels that are removed by a Number 2 sieve in the Carter Day dockage tester or that pass through an $^{8}/_{125}$–inch (.064) by $^{3}/_{8}$–inch screen when using hand sieves. Shrunken and broken kernels are important to flour millers since this wheat is usually removed in the

TABLE 1.
GRADES AND GRADE REQUIREMENTS

	Grades U.S. Nos.				
Grading Factors	**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 classes[2]					
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
Stone	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

[1]Includes damaged kernels (total), foreign material, and shrunken and broken kernels.
[2]Unclassed wheat of any grade may contain not more than 10.0 percent of wheat of other classes.
[3]Includes contrasting classes.
[4]Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance.

cleaning house prior to milling and is sold as mill-feed at a substantial discount compared to flour.

Kernel damage is based on a visual assessment of kernel defects (Figure 1, front inside cover). Pictures of kernel damage in Figure 1 were reproduced from interpretive line slides that are used by grain inspectors. Kernels of wheat with the degree of damage (or more) represented in the picture are "picked" as damaged kernels. These kernels are weighed and reported as a percent for the purpose of assigning a grade. Damaged kernels reduce the intrinsic and sanitary quality of wheat. Some of the most common forms of kernel damage are discussed below.

Heat damage (Figure 1-A) occurs in storage resulting from wheat possessing too high a moisture content, from moisture migration due to convective air currents in the bin, or from localized infestations of stored grain by insects that produce heat. High-moisture grain creates an environment that favors mold growth and heating of the grain, which causes the endosperm to turn dark brown or black. Damaged kernels do not perform like healthy kernels during milling. These heat-damaged kernels produce dark particles when milled and create an undesirable appearance in flour.

Germ damage by mold (Figure 1-B) results in a darkened germ, which, if severe enough, indicates the likelihood of heat damage to the endosperm.

Insect-damaged kernels (Figure 1-C) are detected from the presence of an exit hole by insects that infest the internal portion of the wheat. Larvae grow inside the kernel, feed on the endosperm, excrete frass (fecal material), and shed their exoskeletons during development, which results in increased ash content.

Frost-damaged kernels (Figure 1-D) are detected by a slightly flaked-off bran coat. In sufficient quantity, the damage may lead to more powder bran in the flour, possibly resulting in higher ash. Many flour mills are equipped with cleaning or scouring equipment that lessen the effect of frost-flaked kernels.

Sprouting (Figure 1-E) usually occurs in response to severe weathering in the field after the wheat reaches physiological maturity or in storage due to moisture migration as described under heat damage. Sprouting causes an activation of enzymes that convert the long-chain starch molecules in the endosperm into smaller carbohydrates and simple sugars (see Falling Number Test under Intrinsic Quality Section). Storage proteins that produce gluten are also split into smaller compounds during sprouting and a reduction in mill flour yield may occur.

Scab (Figure 1-F) results from field infection by the Fusarium species during anthesis through kernel filling. Infected wheat heads produce shriveled kernels and, in many instances, mycotoxins. Mycotoxins are toxic metabolites produced by mold (fungus) and jeopardize the sanitary quality of whole grain and their products.

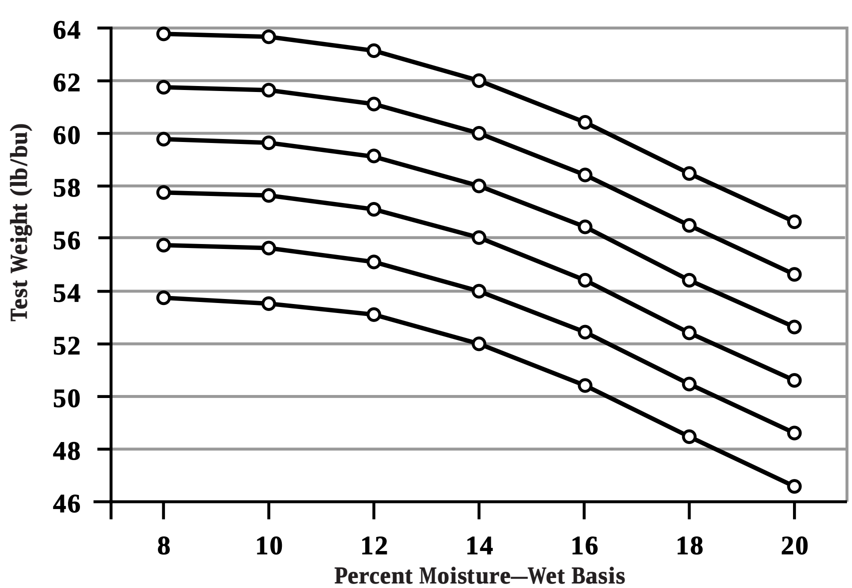
Wheat classification is based on visual techniques that are used to assign kernel color (red or white), growth habit (spring or winter), and hardness (hard or soft). Presently, commercial wheat is divided into eight classes including Durum, Hard Red Spring, Hard Red Winter, Soft Red Winter, Hard White, Soft White, Unclassed, and Mixed. Wheat class reflects the intended end-use of the flour (see Table 2). The present grain inspection system utilizes kernel shape and appearance to distinguish wheat class.

Kernel hardness is an important characteristic since it influences the way wheat performs during processing. "It affects the way in which wheat must be tempered (addition of water to facilitate the removal of the bran from the endosperm during

TABLE 2.
RANGES IN HARDNESS VALUES from the single kernel wheat characterization meter system (SKWCM) for different wheat classes and principle flour use

U.S. Wheat Classes	SKWCM Hardness Value -25 0 25 50 75 100 110	Principle Use
Durum	DUR	Pasta
Hard Red Spring	HRS	Bread, Hearth Bread
Hard Red Winter	HRW	Bread, All Purpose Flour
Hard White	HW	Bread, High Fiber Products
Soft White	SW	Cookies, Cakes, Pastries, Crackers, Breakfast Cereals
Soft Red Winter	SRW	Same as Soft White

FIGURE 2.
RELATIONSHIP BETWEEN TEST WEIGHT AND MOISTURE CONTENT FOR WHEAT
Graph presents the relationship between moisture content and test weight derived from Nelson's equation. For example, the top line represents wheat with a test weight of 63.9 lb/bu at 8% moisture, 62 lb/bu at 14% moisture, and 56.8 lb/bu at 20% moisture.

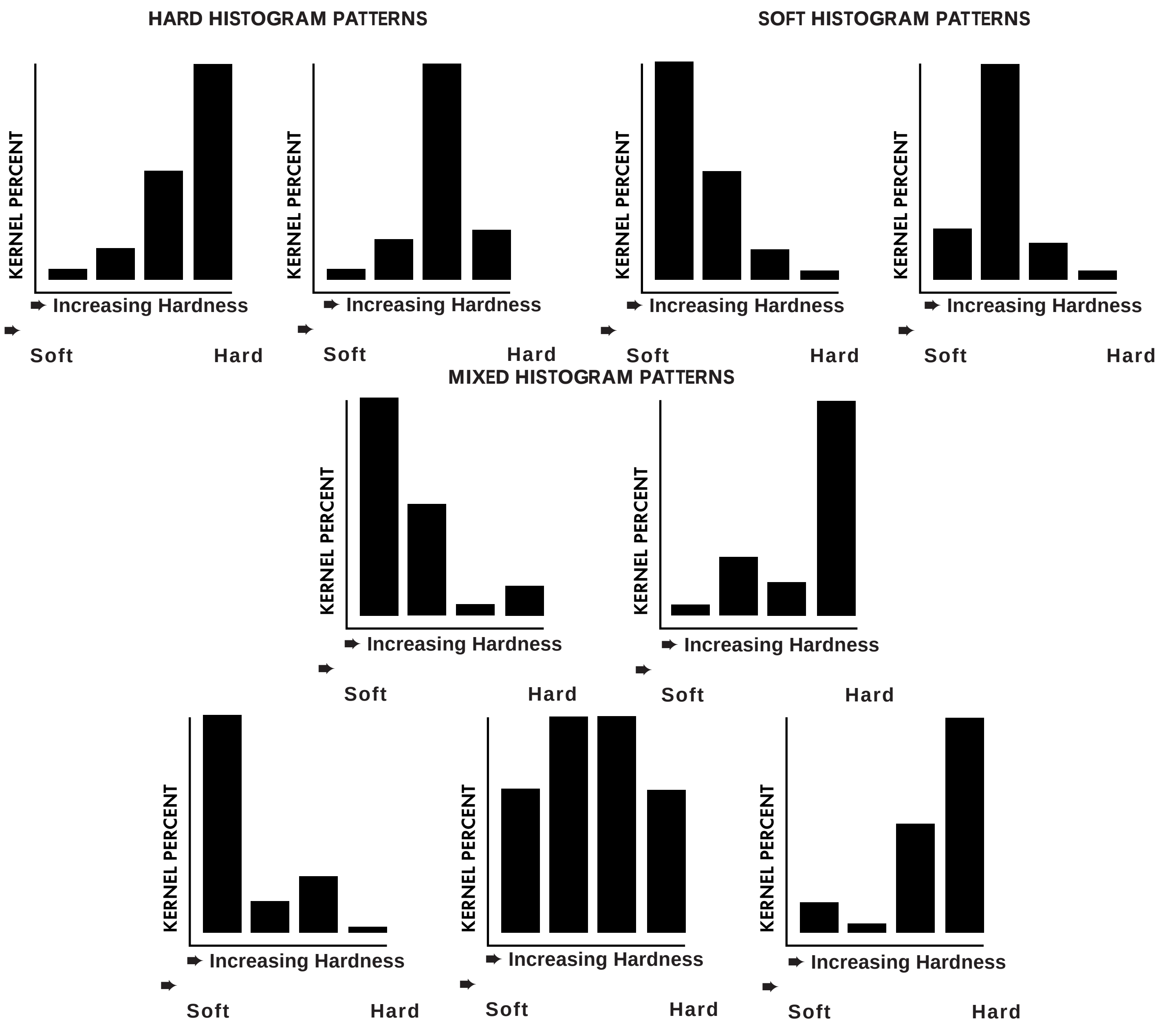


milling); the yield and the particle size, shape, and density of flour particles; and the end-use properties in milling, bread-making, production of soft wheat products, and noodle-making" (Pomeranz, 1992).

Making the transition from a visual classification system to an objective classification system requires the development of new technology. The first of these involves measurement of individual kernel hardness. The "Single Kernel Wheat Characterization Meter" (SKWCM) was developed by ARS engineers at the U.S. Grain Marketing Research Laboratory in Manhattan, Kans., to measure individual kernel hardness. An algorithm that includes crushing force, kernel moisture, and kernel weight calculates the hardness index for a wheat sample. The SKWCM provides a measurement of kernel uniformity (standard deviation) since kernels are evaluated individually rather than as a single measure for the entire sample. The technology of measuring individual kernels permits the separation of wheat lots into three categories: hard, soft, and mixed (Figure 3). The SKWCM cannot differentiate among hard red

FIGURE 3.
OBJECTIVE HARDNESS CLASSIFICATION

The objective classification method requires not only the average hardness result, but also the degrees of ranges of hardness within a sample set to define classes as Soft, Hard, or Mixed. The following definitions and examples illustrate how the classification system could categorize wheats based on hardness. **Hard Wheat:** Wheat having a high hardness score with not more than 10 percent soft kernels, which exhibits a single peak in a 4-part histogram. **Soft Wheat:** Wheat having a low hardness score with not more than 10 percent hard kernels, which exhibits a single peak in a 4-part histogram. **Mixed Wheat:** Wheat that does not meet the definition of Hard or Soft what. These samples may exceed the 10 percent limit for soft wheat in hard wheat or hard wheat in soft wheat. These samples also may exhibit a "double peak" on the histogram. **Double Peak:** A double peak is a bimodal hardness distribution within a sample. A double peak occurs when the sample average measures on one side of the histogram and at least 10 percent of the kernels are on the other side of the histogram and there is at least a 3 percent difference between the adjacent parts.



winter, hard red spring, and hard white wheat due to considerable overlap in the hardness index values (Table 2) of these classes.

The SKWCM also measures individual kernel moisture, size, weight, and the standard deviation for these measurements. Kernel weight and size are important to millers since they help provide additional estimates of milling performance. These measurements, however, are not grade-determining factors.

ARS and FGIS scientists are investigating the use of NIR as a means of characterizing kernel color. An objective measurement of kernel color is necessary, particularly in the case of hard white wheat. Vitreous white wheat kernels normally have an amber color and, under some growing conditions, may appear to have a reddish tint. During the interim period, classification of hard white wheat will be based on visual identification of the particular variety in question (FGIS Program Bulletin 94.19).

Additional measurements of physical quality commonly used by the milling industry but not part of the U.S. Wheat Standards include thousand kernel weight (TKW) and kernel size distribution. Kernel weight is reported in grams (g) per 1,000 kernels on a 12-percent moisture basis. Kernel size distribution is measured by sifting wheat over wire mesh sieves (7w, 9w, and 12w). The percentage of larger kernels left on the seven-wire sieve provides additional information about the potential flour yield. Target values for kernel size and weight established by the Wheat Quality Council are 60 percent or more kernels over the seven-wire and a TKW of more than 30 grams (Curran et al, 1995).

Sanitary and Safety Quality Characteristics

Contaminants that jeopardize the sanitation and safety of wheat include the presence of insects, insect-damaged kernels (IDK), harmful or toxic substances, pesticide residues, fungal infection and mycotoxins, off-odor, and deleterious foreign matter, such as glass and metal fragments.

At the time of sampling, wheat (on the basis of the lot as a whole) may be considered “distinctly low quality” (DLQ) by FGIS if it contains large debris such as two or more stones, pieces of glass, concrete, or other pieces of debris, or if it is obviously affected by unusual conditions that adversely affect its quality in a 1,000-gram sample. Wheat suspected of containing diatomaceous earth (DE) is considered DLQ unless an examination to verify the presence of DE has been requested. Lots of wheat (the economic unit for sale that was sampled and graded, e.g. truck load, rail car) considered DLQ are graded “U.S. Sample Grade.”

Determination of rodent pellets, bird droppings, other animal filth, broken glass, castor beans, cockleburs, Crotalaria seeds, live insect infestation, large stones, unknown foreign substances, and commonly recognized harmful or toxic substances are made on the basis of the sample (usually about 1,000 grams) as a whole (before removal of dockage).

Wheat samples as a whole will cause a lot of wheat to be considered “Sample Grade” by FGIS if they contain the following[1]: eight or more stones or any number of stones with an aggregate weight greater than 0.2 percent of the sample weight; two or more castor beans (*Ricinus communis L.*); four or more particles of an unknown foreign substance or a commonly recognized harmful or toxic substance; two or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1,000 grams of wheat; has a musty, sour, or commercially objectionable foreign odor (such as persistent fumigant or insecticide odors); or is heating or otherwise of distinctly low quality (Table 1). Thirty-two or more insect-damaged kernels per 100 grams (about 3,350 kernels) of wheat (dockage, shriveled, and broken free wheat) will also cause a lot of wheat to be graded “Sample Grade.”

The FGIS and the Food and Drug Administration (FDA) have implemented a Memorandum of Understanding (MOU) that specifies the above levels of contaminants in wheat are actionable and will be cross-reported.

The presence of any live weevil or any other live insect injurious to stored grain indicates the probability of infestation and warns the wheat must be carefully examined to determine if it is infested. To reflect the presence of live infestation in a lot of wheat, the FGIS in 1988 revised the special grade designation from “WEEVILY” to “INFESTED” and changed the combination of insects required to cause a lot of wheat to be graded “INFESTED.” The special grade designation is appended to the numerical grade (i.e. U.S. No. 1, 2, etc.) that is determined on the basis of physical quality characteristics. In effect, any two live insects, either weevils or other live insects injurious to wheat, will cause the lot to be graded “infested.”

In 1977, prior to the MOU with FGIS, the FDA established “Defect Action Levels” (DALs) for insect and rodent contamination in wheat for human consumption. The DALs indicate the natural or unavoidable levels of contamination that constitute no health hazard.

Thirty-two or more insect-damaged kernels per 100 grams is considered subject to action by the FDA (FDA Policy Compliance Guide 7104.03). Insect-damaged kernels (IDK) are those that show evidence of tunneling or boring (Figure 4). Occasionally, wheat kernels that meet this criteria are found in samples coming directly from the field. It has not been established whether these damaged kernels are due to “stored-grain” insects or field insects. The FDA Policy Compliance Guide also includes a “defect action level” for rodent excreta in wheat for human consumption. Nine milligrams or more of rodent excreta per kilogram of wheat will cause the lot to be considered actionable. A lot of wheat may also be considered actionable if there is clear-cut evidence of uneven

[1]Based on a dockage-free sample.

loading or plugging, and wheat from any identifiable portion of the load meets the preceding criteria for insect-damaged kernels or rodent excreta pellets.

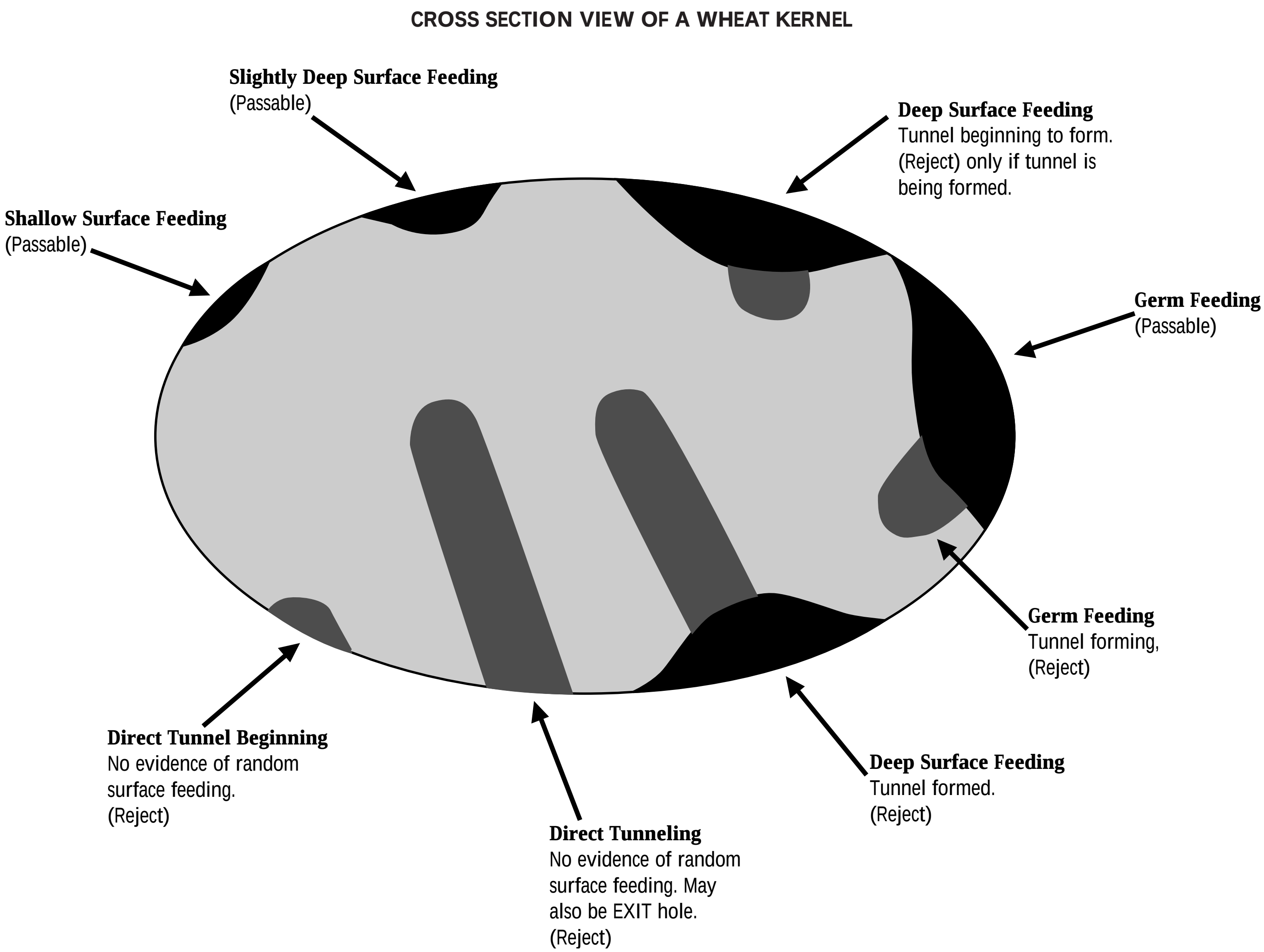
The FDA's DALs for insect-damaged kernels and rodent excreta in wheat for human consumption are directed at assuring insect- and rodent-contaminated wheat is not used in the production of flour and other milled products. Grain exceeding these action levels are subject to removal from interstate commerce.

To further limit the insect and rodent contamination in wheat flour, the FDA has established DALs of 75 or more insect fragments and one or more rodent hairs or fragments per 50 grams of flour (FDA Compliance Policy Guide 7104.06).

In our food marketing system, however, we find that most flour millers would prefer to purchase wheat with five or fewer insect-damaged kernels and less rodent contamination than considered "unavoidable" so they can meet their bakery customers' specifications for much lower insect fragment and rodent hair counts than considered "unavoidable."

Mold-damaged kernels in a lot of wheat are included as a part of the physical (intrinsic) characteristics used to determine the numerical grade of the lot. Mold-damaged kernels and musty or sour odors can be an indication the lot of wheat has been subjected to conditions where toxins may have been produced in the grain. The FDA has established a DAL of 20 parts per billion (ppb) for aflatoxins in grain and food products for human and animal consumption. Fortunately for wheat producers, aflatoxins are rare in wheat and are more commonly found in corn. However, in years when the maturing and harvesting seasons are damp and cool, wheat and other small grains may be subject to "scab" infections caused by the mold *Fusarium graminearum*. This fungus can result in shriveled, lightweight kernels that may appear pink or chalky-white (tombstone kernels, Figure 1-F). In

FIGURE 4.
CLASSIFICATION OF INSECT DAMAGE IN WHEAT KERNELS



addition, the toxin deoxynivalenol (DON), also called vomitoxin, may be produced in the wheat.

In 1993, the FDA established new advisory levels for vomitoxin in wheat. These guidelines (Table 3) advised that DON should not exceed 1 part per million (ppm) in finished wheat products for human consumption. FDA did not state an advisory level for wheat intended for milling because normal manufacturing practices and additional technology available to millers can reduce DON levels substantially in finished wheat products from those found in the wheat.

Symptoms produced by DON-contaminated wheat fed to swine and other animals include refusal to eat (swine), digestive disorders, diarrhea, and ultimately death. Advisory levels for use in animal feeding were suggested by the FDA (Table 3). Advisory levels serve as guidelines that grain handlers, feeders, and processors follow voluntarily. The significance of DON in human health is yet to be demonstrated (CAST, 1989).

The detection of DON and other mycotoxins in wheat and other grains has been greatly simplified through biotechnology using antibodies for specific toxins and other rapid methods. This technology is available in various kits for rapid testing with minimal laboratory equipment. The FGIS and many laboratories offer mycotoxin testing for a fee.

The Environmental Protection Agency (EPA) has established pesticide residue tolerances for cereal grains including wheat. Tolerances have been established for only a few insecticides (grain protectants) that are labeled for direct application to wheat to prevent infestation (Table 4). Only those pesticides labeled for application to specific grains can be applied, and residues must be at or below the established tolerance. Similarly, only a few fumigants are labeled for disinfesting grains. Tolerances for these fumigants have also been established (Table 5). Tolerances have also been established on grains for some pesticides that may have been applied to the growing crop in the field.

Some export customers have established pesticide tolerances below those specified by the EPA. Lists of specified tolerances for various export customers are available from U.S. Wheat Associates or state wheat commissions.

The EPA has recently directed its efforts to promoting integrated pest management (IPM) practices in the post-harvest handling of grains. One goal of IPM is to reduce pesticide use and residue to a minimum.

Intrinsic Quality Characteristics

Intrinsic quality characteristics determine the milling and bread-making (end-use) performance of hard wheat. These characteristics include protein content and quality, falling number, flour yield, ash content, flour color, bread-loaf volume, grain, texture, and color. Hard winter wheat varieties with exceptional intrinsic qualities possess the genetic potential to produce large, uniform kernels with high protein content and good milling and baking performance under favorable growing conditions (Bequette et al, 1994). Identity-preserved marketing capitalizes on

TABLE 3.
FDA ADVISORY LEVELS FOR DEOXYNIVALENOL (DON)

1 ppm	Finished wheat products, e.g. flour, bran and germ, that may potentially be consumed by humans. FDA is not stating an advisory level for wheat intended for milling because normal manufacturing practices and additional technology available to millers can substantially reduce DON levels in the finished wheat product from those found in the original raw wheat. Because there is significant variability in manufacturing processes, an advisory level for raw wheat is not practical.
10 ppm	Grains and grain by-products destined for ruminating beef and feedlot cattle older than four months and for chickens with the added recommendation that these ingredients not exceed 50 percent of the diet of cattle or chickens.
5 ppm	Grains and grain by-products destined for swine with the added recommendations that these ingredients not exceed 20 percent of their diet.
5 ppm	Grains and grain by-products destined for all other animals with the added recommendation that these ingredients not exceed 40 percent of their diet.

Source: U.S. Department of Health and Human Services, Food and Drug Administration, September 16, 1993.

TABLE 4.
GRAIN PROTECTANTS

Protectant	Grains	Tolerance
Pyrethrins & Piperonyl butoxide or MGK-26	Wheat, Corn, Barley, Rye, and Rice	3 ppm Pyrethrins 20 ppm Pip. But.
	Sorghum, Oats	1 ppm Pyrethrins 8 ppm Pip. But.
Malathion	Barley, Corn, Oats, Rice, Rye, Sorghum, and Wheat	8 ppm
Chlorpyrifos-methyl (Reldan)	Barley, Oats, Rice, Sorghum, and Wheat	6 ppm
	<u>Milling Fraction (Except Flour)</u>	
	Oats	130 ppm
	Barley, Sorghum	90 ppm
	Rice, Wheat	30 ppm
Pirimiphos-methyl (Actellic)	Corn, Sorghum	8 ppm
	Milling Fractions (Except Flour)	
	Corn, Sorghum	40 ppm
Diatomaceus Earth (DE)	Cereal Grains	Exempt
Bacillus thuringiensis	Cereal Grains	Exempt

TABLE 5.
GRAIN FUMIGANTS

Fumigant	Grain	Tolerance
Methyl Bromide	Barley, Corn, Oats, Rice, Sorghum and Wheat	50 ppm
	Peanuts and Soybeans	200 ppm
Phosphine	Barley, Corn, Millet, Oats, Rice, Rye, Sorghum, Soybeans, and Wheat	0.1 ppm

the added value associated with wheat varieties possessing exceptional intrinsic or sanitary quality.

Wheat flour is unique in its ability to form a strong, cohesive dough that can retain gas and produce a light baked product. Gluten proteins, which are part of the total wheat protein composition, are (largely) responsible for this unique property. Gluten protein resides in the endosperm portion of the wheat kernel (from which flour is made) and functions as a storage protein.

Much of the hard winter wheat flour is utilized by the commercial baking industry in the production of various breads, rolls, and other products. Good quality hard winter wheat flour has desirable properties for making pan breads and rolls; such flour will yield readily mixed, extensible doughs that machine properly in high-speed bakeries and yield products with good volume and crumb characteristics. Hard winter wheat flour is also used for French and other hearth-type breads, pita and similar flat breads, pizza, tortillas, croissants, and other specialty bakery foods. Although not suitable for cakes, hard winter wheat flour is used for producing considerable amounts of sweet bakery foods, such as sweet goods (e.g. coffee cakes, cinnamon rolls), Danish pastry, and puff pastry items. Hard winter wheat flour is used in home baking, either as family flour (sometimes blended with some weaker flour) or as a bread flour.

Protein, like moisture content in wheat, can be measured directly or indirectly. Direct measurement can be performed using the Kjeldahl technique, which employs wet chemistry to measure total nitrogen content. Another direct measurement technique performed by the Leco nitrogen analyzer involves sample combustion and detection of volatilized nitrogen. FGIS adopted the Leco combustible nitrogen analyzer as the official method for calibrating NIR instruments used to measure protein. The NIR method measures the optical properties of protein in wheat based on reflectance or transmittance (depending on the instrument) and can be performed on ground wheat, whole kernels, or flour.

The **market value of protein** will vary based on its supply. Table 6 contains the average annual protein premiums offered for hard red winter wheat protein from 1984 to 1994.

Flour protein levels tend to be about 1 percent less than wheat kernel protein content. A desirable flour protein content to produce white pan bread tends to range between 11 percent and 12 percent.

The FGIS certificates report protein content in wheat at a 12-percent moisture basis. Flour protein content is generally reported at a 14-percent moisture basis. The following formula can be used to adjust protein content to the desired moisture level:

$$\text{\% Protein @ 12\% Moisture Basis} = \frac{\text{\% Protein @ As Is Moisture} \times 88}{100 - (\text{As Is Moisture \%})}$$

For example, 13.2-percent-protein wheat at 10 percent moisture is equivalent to 12.9 percent protein at 12 percent moisture:

$$\text{\% Protein @ 12\% Moisture Basis} = \frac{13.2 \times 88}{100 - 10} = 12.9\%$$

Wet gluten content, which is directly related to protein content, can be measured using a Glutomatic analyzer (back inside cover). This instrument washes out the nongluten material from a sample of flour or finely ground wheat using a 2-percent saline solution. Wet gluten values are generally reported on a percent basis with average values in the mid 20s to lower 30s.

The **mixograph** is an instrument that measures and records the resistance to mixing of flour and water to form dough (back inside cover). The mixograph curve (referred to as the mixogram) represents the formation of gluten. It peaks at optimal dough development and then falls as gluten is broken down by continued mixing (Figure 5). The curve peak provides an estimate of the time required for mixing that properly develops the dough for bread-baking. The rate (or slope) at which the curve falls and narrows after the peak indicates the protein stability to overmixing. Water absorption values obtained from the mixograph provide an estimate of the amount of water required for baking. Commercial bread bakeries operate most efficiently using flour that possesses a high water absorption (63 to 67 percent), medium-long mixing peak (3.5 to 5.5 minutes), and adequate mixing tolerance (1 to 3 minutes past peak). This test is widely used in the United States.

The **farinograph**, similar to the mixograph, is a recording dough mixer that records the resistance dough offers to a pair of rotating sigma blades in a temperature-controlled bowl (back inside cover). The resistance is transmitted to a dynamometer, which in turn is connected to a lever system that traces a curve on a kymograph chart. Water is added to the flour such that the peak of the curve will center on the arbitrary 500 Brabender Unit (BU) line along the

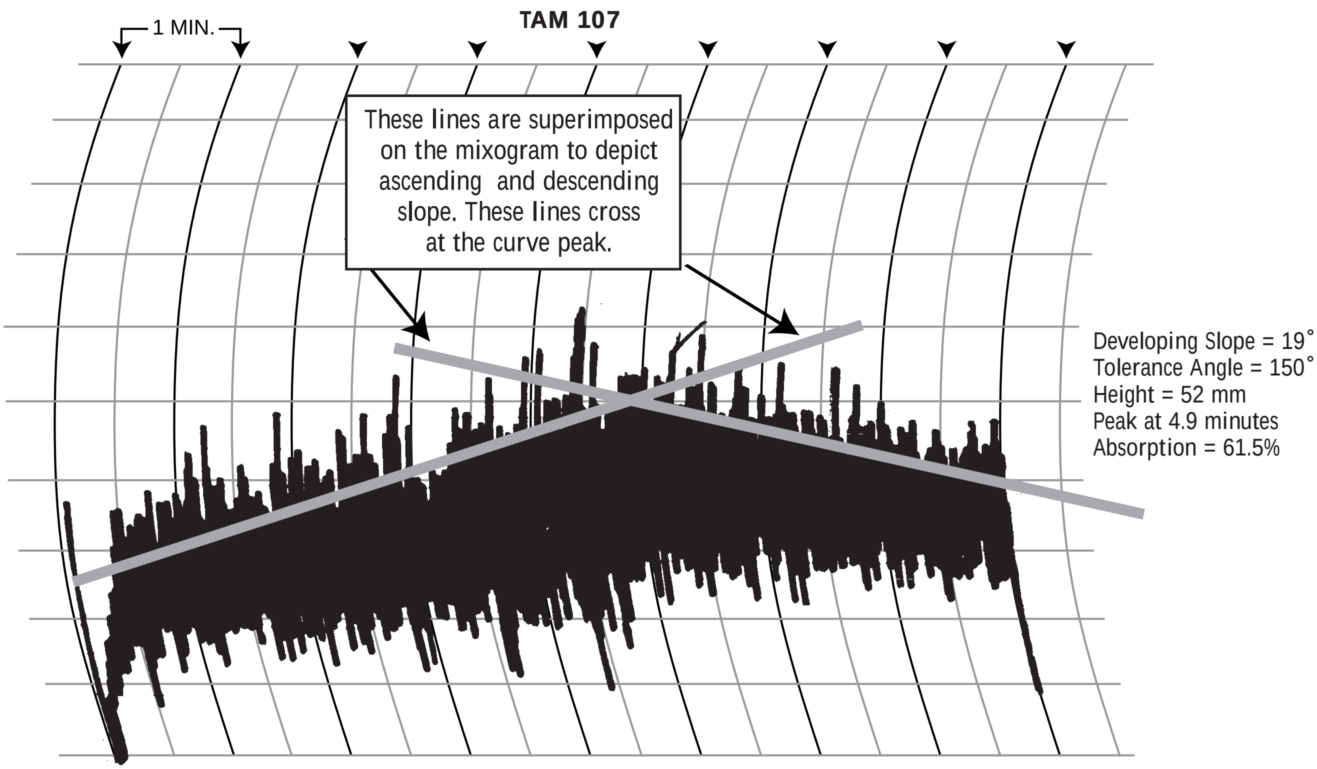
TABLE 6.
PREMIUM OVER ORDINARY HARD RED WINTER WHEAT (in cents per bushel)

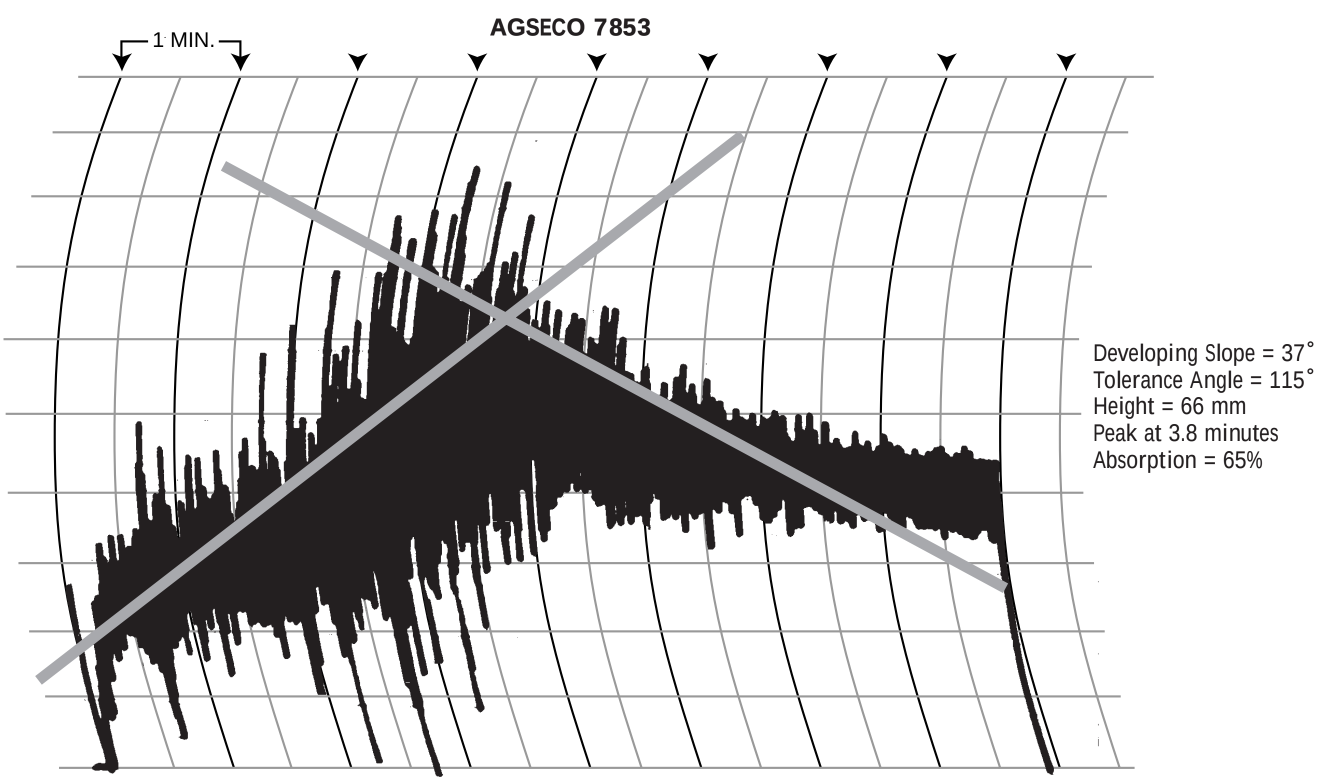
	Year										
Protein	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**
11.0%	1.2	1.5	0.4	0.2	0.3	0.0	0.0	0.0	0.0	1.4	0.3
11.2%	1.6	2.9	0.6	0.3	0.3	0.2	0.1	0.0	0.2	3.0	0.5
11.4%	2.1	4.9	1.1	0.4	0.3	0.3	0.2	0.1	1.3	5.8	0.6
11.6%	2.9	6.8	1.5	0.5	0.4	0.3	0.3	0.1	1.4	11.1	2.1
11.8%	3.9	9.0	2.3	1.6	0.8	0.3	0.6	0.3	1.9	16.3	3.0
12.0%	5.2	12.3	4.0	3.5	0.9	0.4	0.9	0.3	2.4	22.6	3.5
12.2%	7.2	15.8	6.2	5.4	1.4	0.1	1.2	0.5	3.4	27.0	3.7
12.4%	11.3	20.0	9.2	8.6	1.7	0.1	1.7	0.8	4.4	32.3	4.2
12.6%	14.1	24.1	12.0	12.3	1.9	0.0	2.8	1.3	5.4	39.9	4.5
12.8%	15.6	35.1	14.6	14.8	2.2	–0.3	3.9	1.6	6.6	51.4	5.2
13.0%	19.9	35.4	16.7	17.1	2.3	–0.6	7.0	1.9	10.3	67.9	7.5
13.2%	22.5	36.7	18.7	18.9	2.7	–0.6	7.9	2.1	11.0	74..7	8.6
13.4%	25.2	39.9	20.4	21.3	3.2	–1.0	8.8	2.2	12.3	82.6	9.5
13.6%	27.9	43.3	22.2	23.7	3.9	–1.2	9.8	2.4	13.6	91.9	11.8
13.8%	30.5	46.6	23.3	26.2	4.2	–1.4	10.6	2.9	14.7	99.1	13.5
14.0%	33.2	50.0	28.1	28.7	4.9	–1.5	11.7	3.4	18.6	114.3	18.2

middle of the chart. The time required to reach the peak is the development time, when the gluten proteins and the dough are presumably optimally developed. The curve profile, that is the rate at which the dough reaches and then descends from the peak, provides a measure of dough stability against mechanical abuse.

Thus, the farinograph indicates three general properties: amount of water to make a dough, time to optimally mix a dough, and the stability or tolerance of a dough towards mixing. The baker can use this information as a guide to handling a given flour in a bakery. Further, the farinograph curve, or farinogram, may be used as an index of flour

FIGURE 5.
MIXOGRAMS FOR TAM 107 AND AGSECO 7853





uniformity by comparing one curve against other curves representing previous flour shipments. The farinograph has been widely used in flour testing since the 1930s.

The **alveograph** test first involves mixing a flour-water dough under prescribed conditions, forming standardized sample discs of the dough, and clamping the discs onto a retaining plate on the alveograph (back inside cover). A stream of air is directed under the disc, causing the dough sample to inflate into a bubble that expands until it ruptures. The internal pressure in the bubble is measured as a function of time (about one minute) and, from a resulting chart, several measurements are taken that are related to dough and flour quality. Alveograph test results are reported to be related to flour protein content and baking performance and provide information on the relative elasticity or extensibility of dough. The alveograph was introduced in France over 60 years ago and today is widely used in Europe and Latin America in flour-testing programs. Up to this time, the alveograph has not been used in the United States to any extent for hard wheat flour testing. Measurements taken by the alveograph include the area under the curve (referred to as the W value), peak height, and curve length. White pan bread flours measured at Kansas State University's Department of Grain Science and Industry typically displayed W values ranging between 300 and 400.

The **sedimentation** test is a relatively simple means to estimate flour "strength." Coarsely ground wheat is sifted to remove bran, and a sample is first suspended in water then treated with lactic acid solution in a graduated cylinder. After a 5-minute standing period, a sediment composed largely of gluten and some occluded starch is formed and the volume of this material is taken as the sedimentation value. This value is influenced by the quality and quantity of gluten and ranges from 3 for very weak wheat to 70 or more for strong wheat. Because the test requires a relatively small sample and is reasonably replicable, it has proved useful in early-generation wheat-breeding work. The test is used to some extent in the United States in wheat merchandising and by some Latin American markets.

The **Falling Numbers** test is used by milling and baking industries to measure cereal alpha-amylase activity and to detect sprout damage (back inside cover). This test is based on the unique ability of alpha-amylase enzymes, produced during sprouting, to liquefy a starch gel. Liquefaction (breakdown) of the gelatinized starch by alpha-amylase is indicated by the time (in seconds) required for a wire ring to fall to the bottom of the test tube.

Sound wheat will have values of 350 or greater. Wheats with values below 250 can pose problems for flour users. Wheat with a low Falling Numbers value may yield flour that causes bread to be gummy inside or will exhibit a loss of its thickening properties in gravies, soups, and breading flours. Bakers commonly specify a Falling Numbers value in flour contracts, and some export customers, particularly in the Pacific Rim, are including a minimum Falling Numbers specification in wheat contracts. FGIS will perform the Falling Numbers test upon request. This is not part of the grading standards, however.

The **Rapid Visco Analyzer** (RVA) is a new technology that rapidly measures starch viscosity and can accurately estimate the Falling Numbers value (back inside cover). This test was developed in Australia where, in certain years, sprout damage is prevalent, and truckloads of wheat are tested using the RVA upon delivery to the commercial elevator.

The **amylograph** is another instrument used to measure the alpha-amylase activity of flour. For this test, a sample of flour and buffer solution are placed in the amylograph bowl, which rotates at a constant speed and is subjected to a constant temperature increase. Flour starch begins to swell, and the resulting viscosity increase is measured by a series of pins connected to a spring system, which in turn is connected to the recording mechanism. Increased viscosity in the suspension is countered by any alpha-amylase activity, which lowers viscosity proportional to enzyme activity. Thus, the final viscosity reflects the level of alpha-amylase activity. For white pan bread, commercial bakers prefer an amylograph value (referred to as Brabender Units or B.U.) ranging between 500 and 700 B.U.s. The Falling Number test has, in many instances, replaced the amylograph as a method for measuring alpha-amylase activity in the flour milling and baking industry.

Flour yield is important to millers just as grain yield is important to wheat producers. The percentage of flour recovered during milling is referred to as the extraction rate. Although a wheat kernel may be comprised of 85 percent endosperm, a good extraction range for straight-grade flour (all flour streams) ranges from 75 to 80 percent on a clean, dry basis. Millers often refer to flour yield as the number of bushels required to produce a hundredweight of flour. This is particularly beneficial when evaluating the economic return of a lot of wheat as described in the case study below. Flour yield or extraction rate is determined by the amount of endosperm in a wheat kernel and the ease of separating endosperm from bran. Other properties determining milling performance include the power required to reduce large endosperm particles to flour and the sifting properties of endosperm particles and flour. Wheat varieties differ in flour extraction rates by several percentage points, and one variety may have higher or lower flour yields depending on the year and growing conditions.

Flour ash, or mineral content, is given with flour yield as an additional measure of milling performance. The bran coat contains about 10 times more ash than the endosperm. A wheat with good milling characteristics gives a high yield of low-ash flour. Flour ash content is specified by the baker and usually ranges between 0.48 and 0.52 percent.

Flour color can be measured using a number of techniques, both visual and instrumental. This characteristic has diminished in importance as more bakers specify unbleached flour.

Bread characteristics are judged by a combination of objective and subjective evaluations applied to external and internal loaf properties. Externally, loaf volume is of particular importance because it indicates the inherent bread-making potential of a flour. This characteristic is typically measured by an instrument using rape seed displacement (outside back cover). Crust color and loaf symmetry are also external factors. Other external factors include break, the horizontal separation that usually occurs along one side of the bread, and shred, the vertical striations just above the break. Both of these factors should be smooth and uniform. Important internal characteristics include crumb structure, in terms of cell size and uniformity, and crumb color, which may be judged visually or by means of an instrument. Crumb textural properties, or firmness, may be estimated subjectively or objectively by any of a number of instruments. Flavor of the bread is, of course, important and is routinely judged subjectively but can be objectively characterized by means of a sensory taste panel.

Case Study: Economic and Quality Comparisons

A comparison of physical and intrinsic qualities between two wheat varieties (AGSECO 7853 and TAM 107) is performed to help illustrate the value of wheat quality. The wheat used in this comparison was produced in nine western Kansas Extension demonstration plots. AGSECO 7853 possesses superior milling and bread-baking properties and occupied about 2 percent of the seeded wheat acreage in Kansas in 1995. TAM 107 tends to exhibit some less desirable flour and bread-making properties, including a yellowish tint in both flour and bread and lower protein content. This variety occupied approximately 20 percent of Kansas wheat acreage in 1994.

AGSECO 7853 kernels were bigger, heavier, and contained a higher protein content compared to TAM 107 (Table 7). AGSECO 7853 wheat yielded more flour that was whiter, possessed a higher mixograph absorption, and produced a larger loaf of bread with better internal loaf color and texture compared to TAM 107.

The TAM 107 flour mixogram has a peak mixing time of 4.9 minutes. The developing (ascending) slope is 19˚ and the angle between the developing slope and the weakening (descending) slope is 150˚. The developing slope indicates the rate at which the dough develops, whereas the angle between slopes indicates mixing tolerance. The AGSECO 7853 flour mixogram has a peak mixing time of 3.8 minutes. The developing slope is 37˚ and the angle between the developing slope and the weakening slope is 115˚.

Note that AGSECO 7853 mixogram is higher on the paper than the TAM 107. The height of the mixogram is a function of the protein content of the flour. TAM 107 flour protein content was 10.1 percent, whereas the AGSECO 7853 flour protein content was 11.8 percent (Table 7).

The mill yields for TAM 107 and AGSECO 7853 are calculated below using their respective extraction rates of 71.3 and 72.3 percent. Flour yield, expressed as bushels of wheat to produce a hundredweight of flour, can be calculated by dividing 1.667 (wheat bushels equivalent to 100 pounds) by the flour extraction rate then multiplying by 100. The price of wheat in this case example was $4 per bushel and the average mill feed price was $0.0349 per pound.

Flour yields and the raw-material cost of producing one hundredweight of flour with TAM 107 and AGSECO 7853 are presented in Table 8. The difference in raw material cost between TAM 107 and AGSECO 7853 was $0.128 per hundredweight of flour. The value of mill-feed by-product (based on Kansas City June-May) for TAM 107 was $0.0675 greater per hundredweight of flour produced compared to AGSECO 7853. The lower raw material cost for AGSECO 7853 ($0.128) minus the mill feed value from TAM 107 ($0.0675) equates to a savings of $0.0605 per hundredweight of flour using AGSECO 7853. This is equivalent to $605 per day in a 10,000-hundredweight mill. Flour extraction percentage was acquired using a Brabender Quadramate Senior laboratory mill (inside back cover).

Protein premiums may represent significant value during marketing years when the supply of high-protein wheat is low. During the 1993 marketing year, the average price spread between 11 percent

TABLE 7.
CASE STUDY evaluating the physical and intrinsic quality of AGSECO 7853 and TAM 107 produced at 9 locations in western Kansas in 1993

	AGSECO 7853	TAM 107
Physical Quality		
Test Weight	58.7 lbs/bu	56.7 lbs/bu
Kernel Hardness	64	65
Kernel Size	2.72 mm	2.45 mm
Kernel Weight	34.5 mg	30.9 mg
Kernel Protein	12.8%	11.0%
Intrinsic Quality		
Flour Protein	11.84%	10.12%
Flour Extraction	72.3%	71.3%
Flour Color	85.3	80.3
Mixogram Absorption	65%	61.5%
Mixogram Peak	3.8 minutes	4.9 minutes
Bread Loaf Volume	972 cc	915 cc
Bread Color	Bright White	Yellow

protein Hard Red Winter wheat and 12.8-percent-protein Hard Red Winter wheat was $0.50 per bushel (Table 6).

Farmers usually select wheat varieties based on agronomic characteristics that provide the highest yield potential in their fields (environment). While both TAM 107 and AGSECO 7853 exhibit similar yield potential in western Kansas (50 bushels per acre), based on Kansas State University Variety Performance Tests, producers continue to plant a substantial amount of TAM 107. Marketing incentives (premiums, contracts, or dividends from identity preserved marketing of AGSECO 7853) would encourage farmers to plant more AGSECO 7853. In this case example, the added value from improved milling performance and protein content was $0.526 per bushel during the 1993 marketing season.

Future Technology for Measuring Quality

Investigations are underway to develop new procedures to assess or predict the biochemical composition of grain that influences milling and bread-baking characteristics. These technologies rely upon near infrared, nuclear magnetic resonance, and infrared spectral analysis. Such measurements may provide rapid, nondestructive measurements of grain quality that may predict end-use properties presently measured by techniques such as falling number, mixograph, and bake tests.

Digital image analysis is being explored as a method to automate the identification of kernel damage and differentiation between hard red winter and hard red spring wheat. The development of an automated method for detecting off-odor in grain will utilize gas chromatography. Renewed interest in the use of acoustical sensors to detect stored grain insect infestation has lead to a reinvestigation into this area. Development of more sensitive, solid-state electronics since the 1950s, when acoustical detection of insect infestations was first explored, may render this method as a viable option in an automated grain-grading system.

This research should spawn new technologies that will facilitate the transition to an objective grain-inspection system that will augment quality-oriented marketing of wheat.

Summary

Domestic mills and bakeries have become highly automated and process large quantities of wheat and flour. Their demand for a uniform product with specific qualities has become more important. Many export customers are no longer represented by a single government buying agency. The privatization of these economies has been accompanied by an increased demand for wheat quality. Understanding customer needs and the evaluation techniques used to measure end-use quality affords greater opportunity to increase or preserve profits in the U.S. grain industry.

Growers, grain handlers, and merchandisers can realize added value when they market wheat that meets specific quality characteristics for their customers. Producers should consider the market for which they are producing wheat and select varieties that possess superior agronomic and end-use qualities. As the milling industry shifts from a production orientation to a customer orientation, the demand for wheat with specific qualities will continue to increase.

Public concern about food safety and the commitment by U.S. millers and bakers to provide safe, wholesome food has resulted in sanitary quality standards for wheat that are many times more stringent than those imposed by the Food and Drug Administration. In deference to a growing number of customers who prefer pesticide-free products, a significant market has emerged for organically grown wheat. Efforts to preserve the sanitary quality of wheat through the entire production, storage, handling, and milling processes are important quality criteria.

TABLE 8.
ECONOMIC COMPARISON between TAM 107 and AGSECO 7853 for raw material cost and mill by-product value

Mill Yield

TAM 107 @ 71.3% *extraction*

$$\frac{1.667\ bu/cwt}{71.3\%} \times 100 = 2.338\ bu\ per\ cwt\ flour$$

$$2.338\ bu/cwt \times \$4.00/bu = \$9.352/cwt\ of\ flour$$

AGSECO 7853 @ 72.3% *extraction*

$$\frac{1.667\ bu/cwt}{72.3\%} \times 100 = 2.306\ bu\ per\ cwt\ flour$$

$$2.306\ bu/cwt \times \$4.00/bu = \$9.224/cwt\ of\ flour$$

Savings of $0.128 per cwt. of flour using AGSECO 7853

Mill Feed

TAM 107

$$\$.0349/lb \times \frac{2.338\ bu}{cwt} \times \frac{60\ lb}{bu} \times .287\ mill\ feed\ extraction = \$1.405$$

AGSECO 7853

$$\$.0349/lb \times \frac{2.306\ bu}{cwt} \times \frac{60\ lb}{bu} \times .277\ mill\ feed\ extraction = \$1.3376$$

Difference of $0.0675 mill feed value/cwt flour

Added value of AGSECO 7853 = $0.06/cwt flour

Glossary[2]

Absorption

The amount of water required to be added to a particular flour in order for it to function optimally in some application (usually the amount required to make the best possible bread dough), expressed as a percent of the flour weight.

Additive

According to the FDA: any substance, the intended use of which results or may reasonably be expected to result, directly or indirectly, in its becoming a component of, or otherwise affecting, the characteristics of any food.

Adulterate

To clandestinely add some foreign or inferior substance to a food or ingredient, usually for the purpose of making the food material cheaper to produce, as added water would be an adulterant in milk.

Aeration

The process of circulating air upwards or downwards through binned grain to prevent the grain from developing hot spots brought about by heating due to insect and mold development.

Aerated grain bins are fitted with ducts and fans that pull in outside air and push or pull it through the grain mass. Temperature and humidity controls are often used to permit aeration only when those conditions are within the desired limits.

Aging

A step in the milling process in which flour is stored for a considerable time after grinding so its original creamy tint is greatly reduced by natural reactions and its baking quality is improved. Seldom, if ever, used in modern mills in the United States.

Air Classification

A process by which the particles in a mill stream are separated according to size and density by cyclone separators instead of sieves.

All-Purpose Flour

All-purpose flour is a medium-protein wheat flour designed for use in a wide range of food products that are made principally in the home, schools, or small institutions where it is not economical to purchase a number of specialized flours.

Alveograph

An instrument that measures the stretchability of dough; said to provide an indication of baking quality. A standard disc of dough is blown into a bubble, and the pressure change and bursting pressure is charted versus time.

Amylograph

An instrument used to determine change of viscosity with time in a heated mixture of water and a starchy material such as flour.

Ash

The inorganic material left after flour is burned. Frequently included in flour specifications as a criterion of the extraction rate and influences flour/product color.

Aspirator

A grain-cleaning apparatus that utilizes the separation power of air currents to remove low-density impurities such as dust, light chaff, and bran particles from grains or other granular material.

Bake-out

The amount of weight loss undergone by a dough or batter during its passage through the oven.

Baker's Hard Wheat Bread Flour

Baker's Hard Wheat Bread Flour shall be milled only from the classes Hard Red Spring, Hard Red Winter, or Hard White Wheat...and shall meet the following chemical and physical requirements:

Moisture		14.0% Max.
(Following on a 14% moisture basis.)		
Protein (N x 5.7)	11.30% Min.	13.00% Max.
Ash	0.44% Min.	0.48% Max.
Falling Number, (Range)	200 Min.	300 Max.

Baker's Percent

The weight of individual ingredients expressed as a percentage of the weight of flour in the formula. Thus, a dough made from 100 pounds of flour and 60 pounds of water would have 60 percent ingredient water (60 percent absorption).

Beard

The small bristles that grow at one end of the wheat kernel.

Biscuit Flour

A wheat flour milled from soft wheat, or a combination of soft and hard wheats, for the production of chemically leavened biscuits.

Biscuit flour will have an approximate protein content of 9 to 10 percent and an ash content of approximately 0.38 to 0.44 percent.

Bleached Flour

Wheat flour that has been treated with chemicals, such as benzoyl peroxide, in order to increase its whiteness; usually, some maturing action also is exerted by these chemicals.

Bleaching

Treating flour with an oxidizing agent to discolor some of the natural pigments or cause desirable changes in all flour components.

Boerner Divider

The official device used for dividing a grain sample into representative subsamples.

Brabender Extensograph

A dough-testing device used as a supplement to the Brabender Farinograph that measures extensibility and resistance to extension.

[2]Wingfield, 1989. Dictionary of milling terms and equipment. Association of Operative Millers. Leawood, KS, and Matz, S.A., 1993. Glossary of Milling and Baking Terms, Pan-Tech International, Inc. McAllen, TX.

The Extensograph, or Extensigraph, stretches a piece of preformed dough at a constant speed and records the resistance on a moving graph until the dough piece breaks. The resultant curve can be read to show the effect of flour improvers, such as bromate and iodate, which can scarcely be observed on the Farinogram.

Brabender Farinograph

A recording dough mixer.

The Farinograph consists of a mixing bowl, the blades of which are driven by a motor connected to a dynamometer. As the dough develops, a torque is produced on the blades. The dynamometer is connected to a pen that records the torque on a moving graph.

The complete curve for a given dough is called a Farinogram. The Farinogram can be read for the indices of water absorption, mixing time, stability, and mixing tolerance index, all of which can be used to predict how a flour will perform in a commercial bakery.

Bran

In the milling of grain, the fraction consisting mostly of the fibrous outer layers of the kernels.

Bread Scoring

A system of evaluating bread that consists of applying numerical scores to various quality features of the loaf and summing these individual scores to give an overall single-figure characterization of the quality of the product.

Break

(1) One of the first steps by which the grain is reduced to meal in roller milling processes; usually performed by pairs of corrugated steel cylinders.

(2) The portion of inner crust exposed when the outer crust ruptures during oven spring; in a pan loaf of bread, its the lighter and rougher area along the side of the loaf just above the pan top.

Bromated Flour

Potassium bromate is added in a quantity not exceeding 50 parts to each million parts of the finished bromated flour and is added only to flours whose baking qualities are improved by such addition.

Bucky

A bucky dough is tough and dense and resists extension; it tends to tear when stretched. Buckiness is characteristic of a “young” or underfermented dough, but there are other causes as well.

Cake Flour

Cake flour is milled from Soft Red Winter or Soft White Wheat classes of wheat.

The flour should have a 9.3-percent maximum protein (N x 5.7), 0.40-percent maximum ash, 13.5-percent maximum moisture, and a 250-second minimum Falling Number.

Chemical Leavening

Usually some form of baking powder, i.e. a mixture of sodium bicarbonate with an acid-reacting substance. Ammonium bicarbonate is also in this category.

Chlorination

Adding small amounts of chlorine gas to wheat flour in order to whiten it and improve its quality for cake baking.

Clear Flour

The portion of flour remaining after the “patent” mill streams have been diverted.

Clearing Time

Time from beginning of mixing until the dough forms into a single mass and takes up the material smeared on the back of the bowl.

Color Test

A test often applied to cereal products to determine their quality.

The color of white products can be checked by the eye using the Pekar test or by using some type of instrument such as the Kent-Jones or Agtron color meters. Flours may be dark or dull due to poor milling or due to the presence of nonwhite contaminants such as bran. Nonwhite cereal products may be checked for their desired color, such as yellow for corn and durum products. In any color test the effect of granulation on color must be negated, if at all possible, as changes in color due to granulation will not affect the color of the baked product.

Conditioning

The process of adding water, steam, or a combination of both to grain. As the recommended levels of moisture for the storage of grain are usually below the desirable moisture levels for milling, it is usually necessary to add water after cleaning and before milling. The addition of water brings about changes in the grain kernel that facilitate the removal of the bran from the endosperm and reduce the energy necessary for endosperm reduction. The use of heat in the conditioning process shortens the time needed for complete absorption of the water and, if excess heat is applied, it may change the functional properties of the grain.

Also referred to as TEMPERING or WETTING.

Cookie Flour

A flour milled from lower-protein soft wheats.

Cookie flour is used in the production of cookies and has an approximate protein content of 7.5 to 8.5 percent (N x 5.7) and an ash content of approximately 0.40 to 0.46 percent, both on a 14-percent moisture basis.

Cracker Flour

A flour milled from 100-percent Soft Red Winter wheat or from a blend of hard and soft wheats.

Most cracker flours are a blend, containing between 20 and 40 percent hard winter. Cracker flour varies between an 85-percent patent and a straight-grade flour, with a 95-percent patent being typical, having a protein content between 8 and 10 percent and an ash content between 0.38 and 0.44 percent. The lower-protein cracker flours are used for crackers made by the straight dough process, while the higher-protein cracker flours are more suitable for the sponge dough process.

Defect Action Levels, FDA

A listing of the maximum amount of certain naturally occurring defects that are allowable in food stuffs sold in interstate commerce.

The Defect Action Levels for Foods are established by the Food and Drug Administration and cover, in addition to many other foods, certain grains and grain products. The defects listed do not constitute a hazard to health. The official statement in the defect pamphlet says: "The action levels are set because it is not now possible, and never has been possible, to grow in open fields, harvest, and process crops that are totally free from natural defects." Cereal foods exceeding the defect action levels listed are unlawful and subject to seizure and penalties. The FDA can also act against cereal foods that are below the Defect Action Levels if the food has been found to be made in violation of the current Good Manufacturing Practices (GMPs).

Disk Separator

A machine containing a set of upright revolving discs covered with small pockets, used in grain cleaning to remove foreign matter that has either a size or shape difference from that of the desired kernels.

Divider

Machine that cuts masses of dough into pieces of uniform weight.

Dough Brake

Heavily built machines for pressing a sheet or large chunk of dough between metal rollers that rotate fairly rapidly; their function is to reduce dough thickness, squeezing out most of the gas and orienting the fibrils of the gluten as part of the processing of bread doughs and the like.

Drum Molder

A machine that forms bread loaves by pressing dough pieces between a rotating drum and an outer jacket positioned to leave a channel between itself and the drum.

Endosperm

The white starch interior material of grain.

Enriched Flour

Enriched flour contains in each pound 2.9 milligrams of thiamine, 1.8 milligrams of riboflavin, 24 milligrams of niacin, and 20 milligrams of iron.

It may contain added calcium in such quantity that the total calcium content is 960 milligrams per pound. Enriched flour may be acidified with monocalcium phosphate within the limits prescribed for "phosphated flour," but if insufficient additional calcium is present to meet the 960 milligram level, no claim may be made on the label for calcium as a nutrient.

It may contain no more than 5 percent by weight of wheat germ or partly defatted wheat germ.

(Self-rising and bromated flour may also be enriched.)

Fancy Patent Flour

The name sometimes applied to soft and hard wheat patent flours having very low ash content used for the production of very white cakes.

Fancy patents may constitute approximately 50 percent or less of the total flour streams produced when milling a given wheat.

First Clear Flour

First clear flour is made up of a selection of the individual flour streams that are not used for the production of short patent flour. This product will have an ash content of approximately 0.75 percent (14 percent M.B.) with an average protein content of 13.2 percent when milled from a hard winter-spring wheat blend and an average protein content of 10 percent when milled from a soft wheat.

Hard wheat first clears are used for blending purposes to strengthen other flours. Soft wheat first clears are used in a variety of food products as thickeners and binders.

Flour Classification System

In the milling and baking trade, most flours are given designations based on their proposed end-product use. These terms are quite general (unless officially defined) and vary considerably between companies and geographic locations. Flours in the United States fall into the broad classifications of:

Cake Flour	All-purpose flour
Cookie flour	Baker's bread flour
Pastry flour	Hearth bread flour
Doughnut flour	Blending flour
Pancake and waffle flour	

These are listed in the general order of lowest to highest protein contents.

Flour Extraction Rate

The amount of flour produced divided by the amount of grain used and expressed as a percentage.

Gluten

A high-protein (75 to 80 percent dry basis) food product obtained by the wet processing or milling of wheat or wheat flour. Also known as vital wheat gluten, gum gluten, or crude gluten.

When wheat flour is made extensible by adding water and mixing, a dough or batter is formed depending on the amount of water added. Most of proteinaceous materials are linked together by this process and can be separated from the starchy materials by a washing process. The wet gluten formed will contain about 60 percent free water that can be removed by drying, and the resulting product is ground into a brownish flour.

Gluten may be used for (1) dough strengthening, (2) gas retention and controlled expansion, (3) structural enhancement due to thermosetting, (4) water absorption and retention allowing improved yields, product softness, and extended shelf life, and (5) natural flavor enhancement. Wheat gluten may be used in breakfast cereals, breadings, batter mixes, pasta, nutritional snacks, meat, poultry, and fish products, and pet foods.

Gradual Reduction

The modern process of milling, in which the goal is to produce middlings rather than to avoid doing so as was the principle before the New Process was introduced. In gradual reduction, the middlings are sized and separated from the bran by sieves and purifiers, and the particles in each size range are reprocessed under conditions particularly suited to that size. The process is repeated until the desired end-products are obtained.

Hagberg Falling Number Test

A quick method of determining the presence of the enzyme alpha-amylase. The Hagberg diastatic number is calculated from the inverse of the liquification time minus the gelatinization time. This test is frequently used to determine the degree of germination in a grain.

Hearth Bread

Originally, loaves or rolls baked on the floor of the oven without the use of pans. Now, often applied to bread or rolls baked in or on pans that do not confine their lateral expansion.

Hearth-Style Flour

Baker's Hard Wheat hearth-style flour shall be milled only from the classes Hard Red Spring, Hard Red Winter, and Hard White and shall meet the following chemical and physical requirements:

Moisture		14.0% Max.
(Following on a 14% moisture basis.)		
Protein (N x 5.7)	13.25% Min.	14.25% Max.
Ash	0.50% Min.	0.55% Max.
Falling Number Range	175 Min.	275 Max.

High-Extraction Flour

Wheat flours containing greater amounts of the aleurone endosperm.

Extraction rates of more than 78 percent are required to make high-extraction flours that release more bran powder, so a darker flour results. High-extraction flours recover more of the total wheat protein but require more energy to produce than the lower extraction rate flours.

Hungarian Process

The modern flour milling system of gradual reduction with rollers and a primitive type of purifier was first put into widespread practice in Hungary, and so, for a time, such milling was called by this name.

Identity Preserved

The characterization of desired traits and quality factors of a variety and the subsequent process of sorting and maintaining that variety by name (or trait) with the intent of increasing the value of the product through the point of sale.

Kjeldahl

A procedure for determining total combined nitrogen in foods. The nitrogen so determined can be multiplied by a factor, such as 5.7 for flour, which gives the approximate protein content of the material.

Laboratory Mill

A milling machine, or a combination of machines, that can extract milled products from small quantities of grain for testing purposes.

Leavening

Anything used to generate gas inside a dough so as to provide the typical internal structure of a baked product. Yeast, baking powder, and ammonium bicarbonate are the most common leaveners. Water vapor and expanding air also contribute to the leavening of baked products.

Long Patent Flour

The name usually applies to flours produced by combining approximately 90 percent or more of the total flour streams produced when milling a given wheat.

Long patents are normally used for the production of yeast-raised products such as pan breads.

Low-Grade Flour

Wheat flour made by combining those individual flour streams having a higher amount of bran specks.

Low-grade flours are somewhat gray to brown in color, with a higher protein content than the wheat from which they are milled. Minimum ash is approximately 1 percent.

Low-grade flours may be sent to a starch or gluten washing plant for recovery of the gluten, sold for feed, or for various industrial uses, such as a filler and binder for charcoal briquettes.

Even though one low-grade flour may be taken by a mill, it may be referred to as second low-grade flour.

Middlings (Wheat)

Consists of fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the offal from the "tail of the mill" (Red Dog). This product must be obtained in the usual process of commercial milling and must contain no more than 9.5 percent crude fiber.

Milling Yield

The amount of flour, or other major products, obtained from a given lot of grain. Many different methods are used to report milling yields. They include:

1. Yield by bushel. The amount of grain, in bushels, required to make 1 hundredweight (100 pounds) of flour.

2. Yield by pounds. The amount of grain, in pounds, required to make 1 hundredweight (100 pounds) of flour.

Yields are also reported on different types of grain basis.

Some examples are:

1. Dry, dirty grain yield. The flour produced is divided by the grain used before it is cleaned or tempered. This type of yield reporting is used to determine the cost of raw grain used to produce a given amount of flour. This type of yield is important from an economic sense but is of lesser importance to indicate milling efficiency.

Sometimes referred to as a gross yield.

2. Dry, clean grain yield. The flour produced is divided by the grain used after it has been cleaned but before tempering. This type of yield reporting eliminates the dockage and foreign material (screenings) factors. This type of yield can be compared to the dry, dirty grain yield to see the effect of cleaning on yields. The yield can be obtained by subtracting the percent of screenings produced from the dry, dirty yield.

3. Wet, clean yield. The flour produced is divided by the grain used after it has been cleaned and tempered. This type of yield provides the best milling efficiency, or milling performance, comparison as it is independent of the amount of foreign material or the moisture content on the grain used.

4. Product yield. The flour produced is divided by the total products produced. This yield does not require a wheat scale and provides a quick estimate of mill efficiency.

5. Grand yield. The amount of flour put into the final mode of transportation leaving the mill divided by the amount of grain received. This is a long-term, usually monthly, yield that is the ultimate economic yield as it relates the final amount of product sold to the customer compared to the amount of grain purchased to make the product. It takes into account all types of losses such as moisture loss, loss of flour to feed, theft, invisible losses, etc.

Moisture Basis

The moisture content at which a quantitative assay is reported. Common moisture basis of reporting are:

1. As is. Reported on whatever moisture basis the original sample was. Grain proteins, as an example, are commonly reported on this basis.

2. Dry matter. Reported on a zero-water-content basis. Most scientific reporting is on this basis as it eliminates moisture as a variable.

3. 14 percent moisture. Flour results are often reported on this basis as it is milled at or near this moisture content.

Mixing Tolerance

The relative capacity of a dough to withstand changes in mixing conditions, especially variations in mixing times.

No-Time Doughs

A straight dough, which through the use of more fermenting agents and higher temperatures than normal and usually with the aid of more mechanical development in the form of mixing, has its fermentation period reduced from hours to less than 20 minutes. These doughs are sent to make-up immediately after mixing, with a generally unregulated floor time during which some fermentation occurs.

Offals

The combined by-products obtained from the milling of wheat consisting of bran and fine wheat feed. (British)

The remaining or rejected materials resulting from the reduction process.

One Thousand Kernel Weight (TKW)

The weight of 1,000 kernels of a grain expressed in grams.

Oven Spring

The expansion of the loaf that occurs during baking.

Pastry Flour

Flour milled from either the Soft Red Winter or White Wheat classes.

The flour shall have a maximum moisture of 14 percent, a maximum protein of 10.5 percent ($N \times 5.7$), an ash content between 0.41 percent and 0.47 percent, both on a 14-percent moisture basis and a Falling Number of 250.

Patent Flour

The term PATENT, as applied to wheat flour grades, originates from the use of patented processes introduced in the late 19th and early 20th centuries, which made use of the purifier to produce extra white, low-ash flours. Today, patent flours are produced by combining the white, lower-ash flour streams during the milling process.

Proof Box

A chamber or room equipped with means for maintaining relatively constant temperature and humidity and for transporting dough containers such as loaf pans through the space.

Proofing

The final rising of bread dough (except for oven spring) occurring after the dough has been formed into the final piece.

Recovery Periods

The rest stages that allow dough pieces to accumulate gas and the gluten to relax following, for example, rounding.

Red Dog

Consists of the offal from the “tail of the mill” together with some fine particles of wheat bran, wheat germ, and wheat flour. This product must be obtained in the usual process of commercial milling and must contain not more than 4 percent crude fiber.

Rounding

Rolling cut dough pieces coming from the divider so as to seal the surfaces and form a uniform skin on the pieces.

Sedimentation Test

A test for evaluating gluten protein quality; flour is suspended in an aqueous solution of lactic acid and alcohol and held for a time under specified conditions. The volume occupied by the sediment is measured.

Self-Rising Flour

Self-rising flour is a mixture of flour, sodium bicarbonate, and one or more of the acid-reacting substances monocalcium phosphate, sodium acid pyrophosphate, and sodium phosphate.

Shaker, Sieve, Testing, Ro-Tap

A device that holds and shakes, for a predetermined period of time, a set of testing sieves.

Short Patent Flour

The name usually applied to flours produced by combining approximately 50 to 90 percent of the total flour streams produced when milling a given wheat.

Short patents are normally used for baked products requiring a very white crumb color and are low in ash content.

Also referred to as TOP PATENT flour.

Shorts

Wheat shorts consist of fine particles of wheat bran, wheat germ, wheat flour, and the offal from the “tail of the mill” (red dog). This product must be obtained in the usual process of commercial milling and must contain not more than 7 percent crude fiber.

Sponge-and-Dough

A method of producing bread in which a sponge is made by mixing a part of the flour with part or all of the water, and, usually, all of the yeast and yeast food; this mixture is allowed to ferment until it is judged to be ready for incorporation with the other ingredients to make the “dough”.

Straight Dough Process

A method of bread-making in which substantially all the ingredients are mixed together at one time and then fermented, as contrasted with the sponge-and-dough process.

Straight-Grade Flour

Wheat flours made by combining all of the individual flour streams made when milling a given wheat. No clears are taken.

Straight-grade flours will have a protein content of approximately 0.8 to 1.2 percent less than the protein of the wheat used, are of a lower color, and higher ash content than patent flours. Straight-grade hard wheat flours are used for yeast-leavened bread products. Straight-grade soft wheat flours are used for cookie, wafer, cracker, pie crust, and thickener production.

Swanson Mixograph

A recording dough mixer.

The Mixograph mixing bowl contains three vertical pins. Four other vertical pins, lowered into the bowl, travel in a planetary motion around the stationary pins. The torque on the mixing bowl, created by the developing dough, is measured by means of its rotational resistance against a spring or an electronic strain gage and is recorded on a moving chart. The complete curve produced for a given dough is called a Mixogram. The Mixogram curve has a shape that can characterize indices similar to those defined for the Farinograph.

Test Weight

The weight of a specific volume of grain as determined by an approved device. U.S. grain standards test the dockage-free sample of grain to determine the pounds per Winchester bushel (2,150.42 cubic inches). Canada and Britain measure test weight in pounds per Imperial bushel (2,219.36 cubic inches). In some countries test weight is measured in kilograms per hectoliter (2.8379 bushels per hectoliter), or 1.288 times pounds per Winchester bushel.

Wheat Bran

Broad flakes of the white, red, or brown outer covering of the wheat kernel including most of the aleurone endosperm layer. Specifications for feed grade bran are usually in the order of 13.5 to more than 20 percent protein ($N \times 5.7$), 2.5 percent fat, and 12 percent fiber (14 percent moisture basis).

Wheat Bran, Heavy

Large (+ No. 8 sieve) pieces of wheat bran with considerable amounts of adhering endosperm.

Heavy bran is usually taken from the first or second break sifter and is used for the production of toasted bran flakes for breakfast cereals. Heavy bran is usually milled from soft white wheat as its bran color and taste is usually preferred.

APPENDIX 1

Grading Wheat

Terms Defined

Definition of Wheat.

Grain that, before the removal of dockage, consists of 50 percent or more common wheat (*Triticum aestivum L.*), club wheat (*T.compactum Host.*), and durum wheat (*T.durum Desf.*) and not more than 10 percent of other grains for which standards have been established under the United States Grain Standards Act and that, after the removal of the dockage, contains 50 percent or more of whole kernels of one or more of these wheats.

Definitions of other terms.

(a) **Classes.** There are eight classes for wheat: Durum wheat, Hard Red Spring wheat, Hard Red Winter wheat, Soft Red Winter wheat, Hard White wheat, Soft White wheat, Unclassed wheat, and Mixed wheat.

- (1) **Durum wheat.** All varieties of white (amber) durum wheat. This class is divided into the following three subclasses:
  - (i) **Hard Amber Durum wheat.** Durum wheat with 75 percent or more of hard and vitreous kernels of amber color.
  - (ii) **Amber Durum wheat.** Durum wheat with 60 percent or more but less than 75 percent of hard and vitreous kernels of amber color.
  - (iii) **Durum wheat.** Durum wheat with less than 60 percent of hard and vitreous kernels of amber color.
- (2) **Hard Red Spring wheat.** All varieties of Hard Red Spring wheat. This class is divided into the following three subclasses:
  - (i) **Dark Northern Spring wheat.** Hard Red Spring wheat with 75 percent or more of dark, hard, and vitreous kernels.
  - (ii) **Northern Spring wheat.** Hard Red Spring wheat with 25 percent or more but less than 75 percent of dark, hard, and vitreous kernels.
  - (iii) **Red Spring wheat.** Hard Red Spring wheat with less than 25 percent of dark, hard, and vitreous kernels.
- (3) **Hard Red Winter wheat.** All varieties of Hard Red Winter wheat. There are no subclasses in this class.
- (4) **Soft Red Winter wheat.** All varieties of Soft Red Winter wheat. There are no subclasses in this class.
- (5) **Hard White wheat.** All hard endosperm white wheat varieties. There are no subclasses in this class.
- (6) **Soft White wheat.** All soft endosperm white wheat varieties. This class is divided into the following three subclasses:
  - (i) **Soft White wheat.** Soft endosperm white wheat varieties that contain not more than 10 percent of white club wheat.
  - (ii) **White Club wheat.** Soft endosperm white club wheat containing not more than 10 percent of other soft white wheats.
  - (iii) **Western White wheat.** Soft white wheat containing more than 10 percent of white club wheat and more than 10 percent of other soft white wheats.
- (7) **Unclassed wheat.** Any variety of wheat that is not classifiable under other criteria provided in the wheat standards. There are no subclasses in this class. This class includes any wheat that is other than red or white in color.
- (8) **Mixed wheat.** Any mixture of wheat that consists of less than 90 percent of one class and more than 10 percent of one other class or a combination of classes that meet the definition of wheat.

(b) **Contrasting classes.** Contrasting classes are:

- (1) Durum wheat, Hard White wheat, Soft White wheat, and Unclassed wheat in the classes Hard Red Spring wheat and Hard Red Winter wheat.
- (2) Hard Red Spring wheat, Hard Red Winter wheat, Hard White wheat, Soft Red Winter wheat, Soft White wheat, and Unclassed wheat in the class Durum wheat.
- (3) Durum wheat and Unclassed wheat in the class Soft Red Winter wheat.
- (4) Durum wheat, Hard Red Spring wheat, Hard Red Winter wheat, Soft Red Winter wheat, and Unclassed wheat in the classes Hard White wheat and Soft White wheat.

(c) **Damaged kernels.** Kernels, pieces of wheat kernels, and other grains that are badly ground-damaged, badly weather-damaged, diseased, frost-damaged, germ-damaged, heat-damaged, insect-bored, mold-damaged, sprout-damaged, or otherwise materially damaged.

(d) **Defects.** Damaged kernels, foreign material, and shrunken and broken kernels. The sum of these three factors may not exceed the limit for the factor defects for each numerical grade.

(e) **Dockage.** All matter other than wheat that can be removed from the original sample by use of an approved device according to procedures prescribed in FGIS instructions. Also, underdeveloped, shriveled, and small pieces of wheat kernels removed in properly separating the material other than wheat and that cannot be recovered by properly rescreening or recleaning.

(f) **Foreign material.** All matter other than wheat that remains in the sample after the removal of dockage and shrunken and broken kernels. Determine the amount of foreign material in wheat by handpicking.

(g) **Heat-damaged kernels.** Kernels, pieces of wheat kernels, and other grains that are materially discolored and damaged by heat that remain in the sample after the removal of dockage and shrunken and broken kernels.

(h) **Other grains.** Barley, corn, cultivated buckwheat, einkorn, emmer, flaxseed, guar, hull-less barley, nongrain sorghum, oats, Polish wheat, popcorn, poulard wheat, rice, rye, safflower, sorghum, soybeans, spelt, sunflower seed, sweet corn, triticale, and wild oats.

(i) **Shrunken and broken kernels.** All matter that passes through a 0.064-inch by 3/8-inch oblong-hole sieve after sieving according to procedures prescribed in the FGIS instructions.

(j) **Sieve—0.064 by $^3/_8$ oblong-hole sieve.** A metal sieve 0.032 inch thick with oblong perforations 0.064 inch by 0.375 ($^3/_8$) inch.

Principles Governing the Application of Standards

Basis of determination

Each determination of heat-damaged kernels, damaged kernels, foreign material, wheat of other classes, contrasting classes, and subclasses is made on the basis of the grain when free from dockage and shrunken and broken kernels. Other determinations not specifically provided for under the general provisions are made on the basis of the grain when free from dockage, except the determination of odor is made on either the basis of the grain as a whole or the grain when free from dockage.

(b) **Grades and grade requirements for Mixed wheat.**
Mixed wheat is graded according to the U.S. numerical and U.S. Sample Grade requirements of the class of wheat that predominates in the mixture, except that the factor wheat of other classes is disregarded.

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 live weevils or other 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.

Grade wheat as follows:

Step 1.
Examine the sample for heating, odor, animal filth, castor beans, crotalaria seeds, garlic, glass, insect infestation, unknown foreign substances, and other unusual conditions.

Step 2.
Divide out a representative portion from the sample and determine its moisture content.

Step 3.
Determine the percentage of dockage in the sample.

Step 4.
Examine the dockage-free sample for ergot, smut, stones, and treated seeds.

Step 5.
Determine the test weight per bushel of the dockage-free sample.

Step 6.
When deemed necessary, divide out a representative portion from the dockage-free sample and determine the percentage of protein.

Step 7.
Divide out a representative portion from the dockage-free sample and determine the percentage of shrunken and broken kernels (SHBN).

Step 8.
When deemed necessary, divide out representative portions from the SHBN-free sample and determine the percentage of class, contrasting classes, damaged kernels, heat-damaged kernels, foreign material, subclass, and wheat of other classes.

Portion Sizes.

Damaged kernels	15 grams
Dockage	250 grams
Foreign material	30 grams
Heating	The lot as a whole.
Infestation	The original sample or lot as a whole.
Moisture	The amount recommended by the instrument manufacturer.
Objectionable odors	The original sample or lot as a whole.
Test weight per bushel	An amount sufficient to cause grain to overflow a kettle.

Procedure for Determining Dockage with Hand Sieves.

Step 1.

Nest the appropriate sieves on top of a bottom pan. Place a 12/64-inch round-hole sieve on top of a 4.5/64-inch round-hole sieve.

Step 2.

Pour the sample into the center of the top sieve, place the sieves in a mechanical grain sizer, set the sizer's time to 20, and turn it on.

If a mechanical sizer is not available, hold the sieves and bottom pan level. Then, using a steady motion, move the sieve from right to left approximately 10 inches and then return from left to right. Repeat this operation 20 times.

Step 3.

Remove the dockage. Consider dockage to be all coarse material that remains on top of the sieves and all material that passed through the bottom sieve.

Test Weight per Bushel.

Test weight per bushel is the weight of the volume of grain that is required to fill a Winchester bushel (2,150.42 cubic inch) to capacity. Since test weight per bushel tends to increase as moisture content decreases, determine it as quickly as possible after the grain is sampled. Determine test weight per bushel after the removal of dockage.

Step 1.

Pour the sample through a funnel into a kettle until the grain overflows the kettle.

Step 2.

After pouring the grain into the kettle, level it off by making three, full-length, zigzag motions with a stroker.

Step 3.

Then weigh the filled kettle on either (1) a special beam scale attached to the funnel stand, (2) an electronic scale programmed to convert gram weight to test weight per bushel, or (3) a standard laboratory scale.

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WHEAT KERNEL DAMAGE

Photos of wheat kernel damage reproduced from interpretive line slides with permission of Seedburo Equipment Company.

BREAD PRODUCTION





Straight-dough bread baking test using 100 g (0.22 pounds) of flour to measure water absorption, mixing requirement, dough machining properties, loaf volume (size), and internal loaf properties including color, grain (cell structure), and texture (feel).

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