5 Wheat Quality in the United States of America

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5.1 Introduction

From before recorded history, through time to this Information Age, wheat has been one of the few global constants. For each of us in this fascinating industry, the more we study and apply the more we realize there is to discover. This chapter does not attempt to cover the entire subject. At best a small light will shine onto some of the many questions that might be asked by millers. The particulars generated in it are from United States based educators whose perceptions have undoubtedly been narrowed by their life experiences.

5.2 Wheat – Historical Perspective

Wheat-type plants such as emmer and einkorn are considered the ancestors of today's wheat plant (see page 1). Researchers do not agree on the exact time and place of the first cultivation of wheat. Most authorities do agree, however, that wheat was an important food source in the Mediterranean region centuries before recorded history. Wheat was not always the predominant grain for human food consumption. Barley and rye were very important grain foods during the Roman Empire and the Middle Ages. Over time, wheat came to be regarded as the best of the cereal foods and dominated both international and domestic trade. Russian Mennonites, who had grown wheat in the Crimea, brought a hard winter wheat called Turkey Red to central Kansas in 1873. Turkey Red, unlike any other wheat at that time, was better suited to soil and weather conditions than the soft and semi-hard wheat early settlers had been growing. Turkey Red spread slowly but became the ancestor of nearly all the hard winter wheat grown in the United States.

5.3 Wheat – Statistical Perspective

Wheat is a significant agricultural commodity in North America and the world, with over two-thirds of the world's wheat production being used for food. The International Grains Council reported that U.S. yearly wheat production from 1990 to 1999 averaged 64.5 mio t, approximately 11.0% of the world's production. Canada averaged an additional 27.4 mio t, or 4.8% of the world total (Tab. 8). U.S. Wheat Associates reported that Hard Red Winter represented approximately 41.5% of the total U.S. wheat production over the same period, making it the largest wheat class of North America. Worldwide production of wheat from 1990 to 2002 averaged 570 mio t (Tab. 9). Only China, the European Union and India with 19.3%, 16.6%, and 11.5% of the world's wheat production grew more wheat than the United States. Based on the average price and production data for 1996 - 2000, the average U.S. wheat crop value was 9,889.90 mio USD. In addition to wheat crop production statistics Fig. 10 shows the world wheat situation with respect to consumption and ending stocks. World wheat stocks are the difference between a year's production and consumption added to the previous year's carry out. This is where the North American wheat industry may tower above the world scene. The U.S. and Canada often provide over 40% of the wheat available for world trade and typically hold over 20% of the world wheat stocks in storage. 20

Without the massive infrastructure for storage and transport, much of North America's wheat would not be available for world consumption.

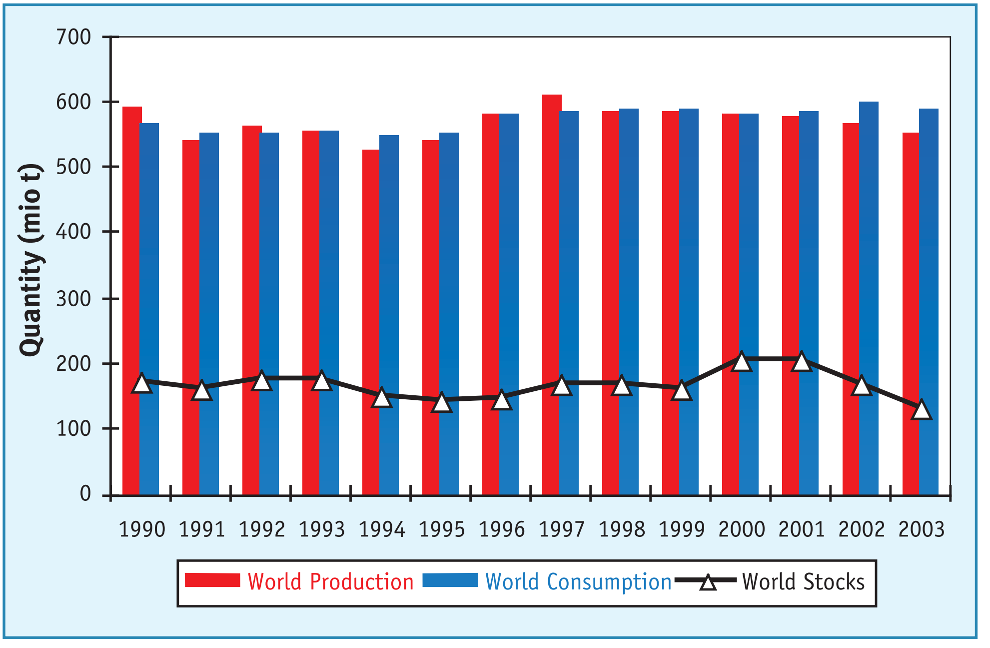


Fig. 10: World wheat production, consumption and ending stocks [3]

Tab. 8: Wheat production – Americas – selected countries [3] (% of world total)

Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Canada	5.42	5.88	5.32	4.89	4.41	4.62	5.12	3.98	4.11	4.60	4.61	3.55	2.77
Mexico	0.66	0.68	0.57	0.64	0.79	0.64	0.58	0.60	0.55	0.52	0.57	0.55	0.58
United States	12.57	9.93	11.92	11.73	11.99	10. 99	10.65	11.07	11.83	10.73	10.46	9.18	7.77
North & Central America	**18.65**	**16.49**	**17.81**	**17.27**	**17.20**	**16.26**	**16.35**	**15.65**	**16.49**	**15.86**	**15.63**	**13.27**	**11.13**
Argentina	1.92	1.82	1.73	1.65	2.15	1.75	2.73	2.43	1.96	2.62	2.84	2.63	2.21
Brazil	0.52	0.57	0.49	0.38	0.41	0.28	0.55	0.39	0.37	0.41	0.29	0.55	0.51
Chile	0.27	0.29	0.24	0.23	0.26	0.20	0.26	0.28	0.20	0.26	0.31	0.29	0.30
Uruguay	0.05	0.06	0.05	0.08	0.07	0.08	0.11	0.08	0.08	0.07	0.09	0.09	0.11
South America	**2.86**	**2.84**	**2.62**	**2.47**	**3.00**	**2.40**	**3.79**	**3.29**	**2.72**	**3.44**	**3.61**	**3.68**	**3.23**
World total (mio t)	**592**	**543**	**562**	**557**	**527**	**541**	**582**	**610**	**586**	**584**	**581**	**581**	**566**

[3] Data for the tables and charts is compiled from selected data provided by the Economic Research Service and Foreign Agriculture Services Marketing Reports of the United States Department of Agriculture

Tab. 9: Wheat production – Americas – selected countries[3] (1,000 t)

Area	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Canada	32,098	31,946	29,871	27,232	23,231	25,017	29,801	24,280	24,076	26,900	26,800	20.600	15,700
Mexico	3,900	3,700	3,200	3,582	4,151	3,468	3,375	3,639	3,232	3,057	3,300	3,200	3,300
United States	74,473	53,914	66,923	65,399	63,167	59,500	61,980	67,534	69,410	62,700	60,800	53,300	44,000
North & Central America	**110,494**	**89,582**	**100,026**	**96,238**	**90,571**	**87,995**	**95,163**	**95,463**	**96,732**	**92,673**	**90,900**	**77,100**	**63,000**
Argentina	11,350	9,883	9,700	9,200	11,306	9,445	15,914	14,800	11,500	15,300	16,500	15,300	12,500
Brazil	3,076	3,078	2,739	2,107	2,185	1,511	3,197	2,380	2,190	2,405	1,700	3,200	2,900
Chile	1,589	1,560	1,322	1,270	1,364	1,070	1,490	1,682	1,197	1,493	1,800	1,700	1,700
Uruguay	300	300	300	450	371	425	620	504	490	400	500	500	600
South America	**16,918**	**15,429**	**14,713**	**13,782**	**15,787**	**13,016**	**22,086**	**20,088**	**15,955**	**20,106**	**21,000**	**21,400**	**18,300**
World Total	**592,383**	**543,134**	**561,641**	**557,314**	**526,633**	**541,237**	**582,147**	**610,129**	**586,485**	**584,460**	**581,400**	**580,800**	**566,200**

5.4 U.S. Grain Grading Standards

Plant breeding lies at the heart of assuring continued improvements in the production and quality of a nation's wheat. Wheat improvement work had its formal beginning in 1897, when the U.S. Department of Agriculture set up an active programme of wheat research and development. Today, the variety development programme is carried out by experiment stations maintained by a number of states as part of their agricultural college and university systems. The experiment stations are the primary source of new wheat varieties and help to maintain the uniformity within a wheat class. Plant scientists at these federal and state stations are guided not only by the need of farmers for high-yielding wheats that resist drought and disease, but also by the quality requirements of millers and bakers at home and abroad.
(Taken from U.S. Wheat Assoc. website)

Today, the United States has eight classes of wheat described by the Federal Grain Inspection Service (FGIS) grain grading standards. They are: hard red winter, soft red winter, hard red spring, soft white, hard white, durum, mixed and un-classed wheat.

The grading standards used in the United States are given in Tab. 15. Important grading characteristics include the percentage of damaged kernels, the percentage of foreign material and the percentage of shrunken and broken kernels as well as the summation of these defects referred to as total defects. All of these factors can negatively impact flour yield and quality and are therefore often removed in the cleaning operation. An additional grading factor is test weight, which is reported in pounds per Winchester bushel[4] in the U.S. and in kg per hectolitre elsewhere. Higher test weights are often indicative of better quality wheat suggesting easier processing and greater flour yield over lower test weight samples. Higher test weight does not, however, always guarantee improved milling characteristics or flour yield because test weight as a single factor does not take into account other important factors such as kernel size, shape and hardness, variety, and other environment-related factors that may influence the resulting flour and/or milling quality (Fig. 11).

[4] There are two conversions for lb/bu to kg/hL.
They are as follows:
Durum wheat kg/hL = lb/bu · 1.292 + 0.630
Other wheat kg/hL = lb/bu · 1.292 + 1.419

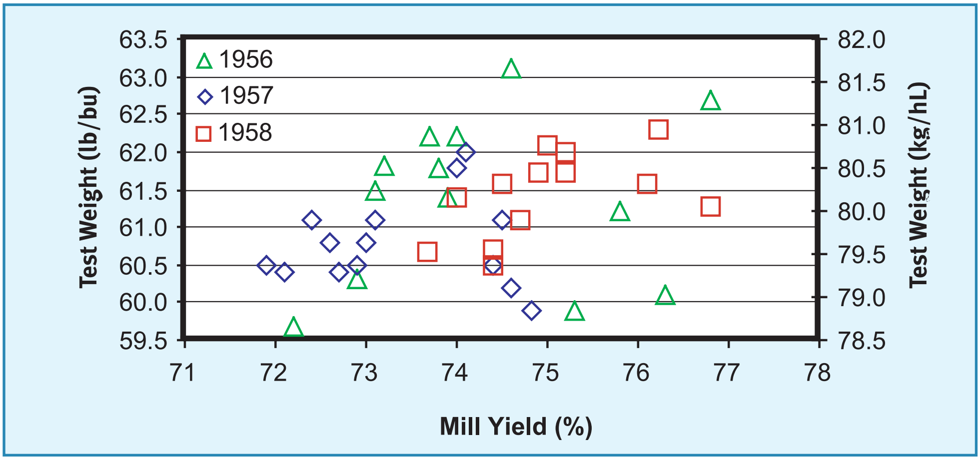


Fig. 11: Influence of test weight on mill yield (after Shuey, 1960)

5.5 U.S. – Six Basic Wheat Classes

There are several hundred varieties of wheat produced in the United States, all of which fall into one of the six recognized classes of economic significance. Each of these six wheat classes has unique milling, baking and processing properties. Unfortunately, grain-grading standards often fail to accurately assess the quality characteristics required to meet end-use performance standards. The six official class groupings can be distinguished from each other in simple, observable ways. The class of a variety is determined by its hardness, the colour of its kernels and by its planting time. Through selective breeding, each class of wheat has developed its own relatively uniform characteristics relating to milling, baking or other food use. The six commercially recognized classes are as follows:

17
80

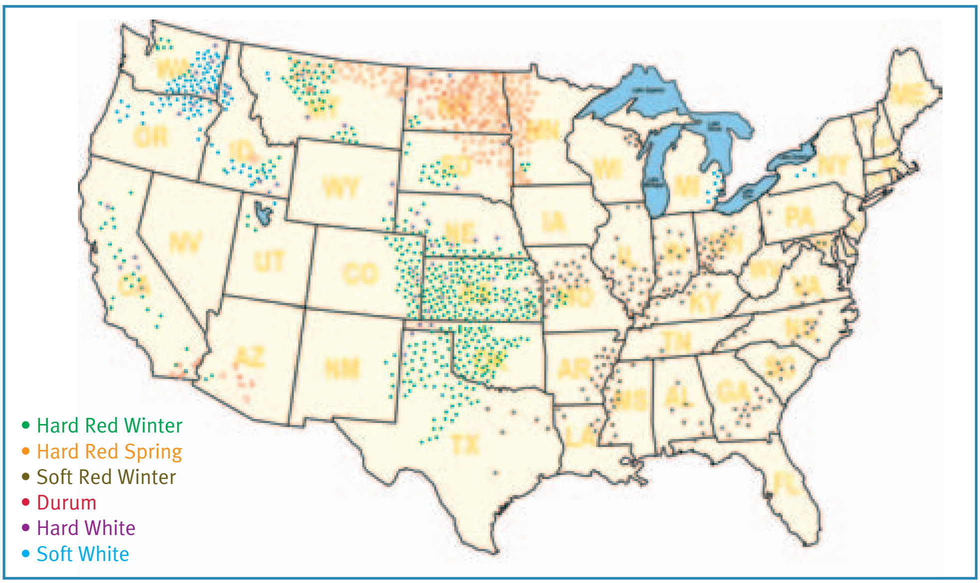


Fig. 12: Areas of U.S. wheat production by class (source: U.S. Wheat Assoc.)

5.5 U.S. – Six Basic Wheat Classes

Hard Red Winter (HRW), an important bread wheat, accounts for almost 40% of the U.S. wheat crop and wheat exports. This autumn-seeded wheat is produced in the Great Plains, which extend from the Mississippi River west to the Rocky Mountains and from the Dakotas and Montana south to Texas (Fig. 12). Significant quantities are also produced in California. HRW has a reddish-brown bran coat; it is of moderate hardness and has mid-level protein content, usually averaging 11 - 12%. It is considered a good milling and baking wheat with characteristics that make it the wheat of choice for much of the North American white pan bread and bun products. There are no subclasses for this class of wheat.

Hard Red Spring (HRS), another important bread wheat, has the highest protein content, usually 13 - 14%, in addition to delivering excellent milling and baking characteristics. This spring-seeded wheat is primarily grown in the north central United States – North Dakota, South Dakota, Minnesota and Montana (Fig. 12). HRS comprises just over 20% of U.S. wheat exports. Subclasses based on the dark, hard and vitreous kernel content (DHV) include **Dark Northern Spring (DNS)**, **Northern Spring and Red Spring**. HRS also has a reddish-brown outer layer.

Hard White (Winter) wheat (HWW) is the newest class of wheat to be grown in the United States. It is used for noodles, yeast breads and flat breads and is grown in California, Idaho, Kansas and Montana (Fig. 12). There are no subclasses. Currently, HWW is used primarily in domestic markets with limited quantities available for export. While similar to HRW in its hardness profile, HWW has a white outer layer that is believed to improve its taste profile in certain products. HWW is not a new crop. Farmers in China grow white wheat varieties and Australia is a major producer of white wheats.

Soft White (SW) is preferred for flat breads, cakes, pastries, crackers and noodles and is grown primarily in the Pacific Northwest (Fig. 12). Soft White is low-protein wheat with soft endosperm and a white outer layer. There are both winter and spring varieties of soft white, but SW is not classified by its growing season. The protein content of this wheat rarely exceeds 10%. SW represents just over 20% of total U.S. exports, primarily to Asia and the Middle East. Subclasses are **Soft White, White Club** and **Western White**.

Soft Red Winter (SRW) is grown in the eastern third of the United States (Fig. 12). SRW yields well for farmers but is relatively low in protein. Although it contains only about 10% protein, this wheat is considered a capable supplier of extensibility to a baker's formula and is therefore used as blending wheat in many export markets. SRW is used for cakes, pastries, flat breads, crackers and snack foods. This autumn-seeded wheat comprises about 14% of U.S. wheat exports. There are no subclasses of this class.

Durum, the hardest of all U.S. wheats, provides semolina for spaghetti, macaroni and other pasta products. This spring-seeded wheat is grown primarily in the same northern areas as hard red spring, while smaller winter-sown quantities are grown in Arizona and California (Fig. 12). Durum comprises nearly 5% of total U.S. wheat exports. Subclasses based on the percentage of vitreous kernel are **Hard Amber Durum** (HAD), **Amber Durum** (AD) and **Durum**.

(Modified from U.S. Wheat Assoc. website. Wheat photographs by courtesy of Roy Chung, U.S. Wheat Assoc.)

5.6 Wheat Evaluation Process – Wheat Evaluation For Grade

Wheat evaluation in the United States is undertaken to ensure general standards of acceptance in flour or semolina production. Many factors are used to determine the wheat class and grade. Physical attributes including colour, shape and hardness determine the class of wheat and the inclusion of contrasting wheat classes. The presence of dockage, foreign material and damaged kernels attests to the overall wheat quality. Test weight provides an indication of kernel soundness and suitability for milling. While factors determining wheat grade are important, they do not completely describe wheat quality.

Wheat quality factors not included in the grading system are critically important to grain storage and milling and baking performance. Moisture and protein content are among the most obvious of these characteristics. Maintaining wheat quality depends on monitoring and controlling moisture content in a safe range. Protein level is often a key characteristic in selection by the miller for the production of bakery flour. Enzymatic (amylase) activity is also an important characteristic of wheat that must be monitored and measured.

Wheat is often milled to produce flour for these tests on automatic and continuous laboratory-scale milling units such as the Brabender Quadrumat Jr. and Senior and Buhler laboratory mills. Wheat may also be milled for evaluation using a host of walking flows which incorporate small-scale stand-alone roller mills and sifters in a batch milling process. These laboratory mills do not completely duplicate the gradual reduction milling processes used in the commercial milling industry. They do however provide the opportunity to rank wheat milling performance and produce flour for further testing and evaluation. Laboratory milling can provide an insight into the milling characteristics of wheat, including bran clean-up, endosperm reduction properties and of course flour yield.

Flour from laboratory milling is often subjected to other testing to determine quality and suitability. Beyond the protein level there is the issue of protein quality, measured by a variety of physiochemical and dough rheology tests including wet and dry gluten, Farinograph, Alveograph, and a host of other recording dough mixers and manipulative tests. While these additional tests may reflect bakery performance and the properties of the finished baked goods, they too fail to describe wheat quality completely.

The final arbiter of wheat suitability and performance is the baking test or, in the case of durum wheat, pasta production and preparation. A laboratory baking test has been established to measure flour performance characteristics in a controlled environment. The formulations do not usually reflect a specific commercial product, but rather the product's principle components at a level that maximizes the influence of flour quality on finished product performance. As with laboratory formulations, the laboratory process does not reflect all possible combinations of factors that one might experience in the commercial bakery. The goal of these procedures is to control and minimize sources of variation so that changes in finished product quality can be attributed to flour characteristics.

Below is a summary of U.S. wheat classes and key performance factors for 1999 - 2004 (Tab. 10).
Fig. 13 shows a flow diagram of standardized sample processing.

5.6.1 Dockage

Dockage is considered to be material other than wheat that can be easily removed (as opposed to Besatz[5]). It is determined with a special machine called the Carter Dockage Tester (Fig. 14). In the U.S. grain grading

[5] *While dockage is the result of a standardized screening process, the term* Besatz *comprises all components of a grain sample which are not perfect grain of the target species.* Besatz *is determined by ICC standard methods 102/1 (wheat) and 103/1 (rye).*

Tab. 10: Summary of key performance factors of U.S. wheat classes 2000 - 2004 [a]

Factor		HRW		HRS		SRW		SW		Durum[b]	
		2004	00-04[c]	2004	00-04[c]	2004	00-04[c]	2004	00-04[c]	2004	00-04[c]
Test weight	lb/bu	58.8	59.6	61.1	60.0	58.2	58.7	60.0	60.0	61.7	59.7
	kg/hL	77.4	78.4	80.4	78.9	76.7	77.2	79.1	79.0	80.3	77.7
Grade		2 HRW	2 HRW	1 NS	1 NS	2 SRW	2 SRW	1 SW	1 SW	1 HAD	2 HAD
Dockage	%	0.7	0.7	1.0	1.2	0.7	0.6	0.7	0.6	1.2	1.5
Wheat											
Moisture	%	11.6	11.6	12.5	11.9	13.5	13.0	9.3	9.2	12.5	11.5
Protein[d]	%	12.7	12.2	13.8	14.5	10.3	10.2	10.3	10.2	13.4	14.2
Ash[e]	%	1.56	1.55	1.56	1.66	1.59	1.56	1.37	1.39	1.50	1.64
1000 kernel weight	g	27.8	28.6	32.0	29.5	31.3	32.4	36.0	34.2	40.2	36.1
Falling Number	s	382	397	339	363	357	341	320	347	356	301
Flour/semolina											
Extraction	%	69.1	70.3	68.7	68.9	69.4	69.9	67.9	66.7	64.3	63.7
Ash[e]	%	0.48	0.49	0.43	0.45	0.45	0.44	0.37	0.36	0.64	0.69
Wet gluten	%	31.2	28.4	32.9	35.9	22.1	22.3	23.0	22.7	35.0	37.2
Farinograph											
Peak time	min	6.6	5.8	10.1	11.6	1.6	1.7	1.5	1.5	n.a.	n.a.
Stability	min	12.4	10.8	15.5	20.5	3.0	3.2	2.9	2.7	n.a.	n.a.
Absorption	%	59.2	59.5	65.1	64.9	53.1	52.6	50.5	50.3	n.a.	n.a.
Alveograph W	$J \cdot 10^{-4}$	320	290	471	385	90	88	102	113	96	n.a.
Loaf volume	mL	844	839	1036	1062	723	750	n.a.	n.a.	n.a.	n.a.
Production	**mio t**	**23.3**	**22.5**	**14.4**	**12.4**	**10.4**	**10.7**	**7.2**	**7.0**	**2.5**	**2.4**

[a] *Courtesy of U.S. Wheat Associates, Washington, D.C.*
[b] *Great Plains durum only, extraction and ash values are for semolina.*
[c] *5-year average*
[d] *12% moisture basis*
[e] *14% moisture basis*

system, dockage does not influence the numerical grade. It is important as the first step in the grading process because the dockage is removed prior to test weight measurement. It is also important in describing the condition of the wheat, and the percentage of dockage is therefore recorded on the certificate by the inspector. Using aspiration (air) and a combination of riddles and sieves, the Carter Dockage Tester prepares a sample for grading by removing the readily separable material. Generally speaking, this material consists of all matter that is lighter than, larger than, or smaller than wheat. The material removed by a dockage tester is readily separated and does not require the additional sophisticated equipment found in the mill's cleaning house.

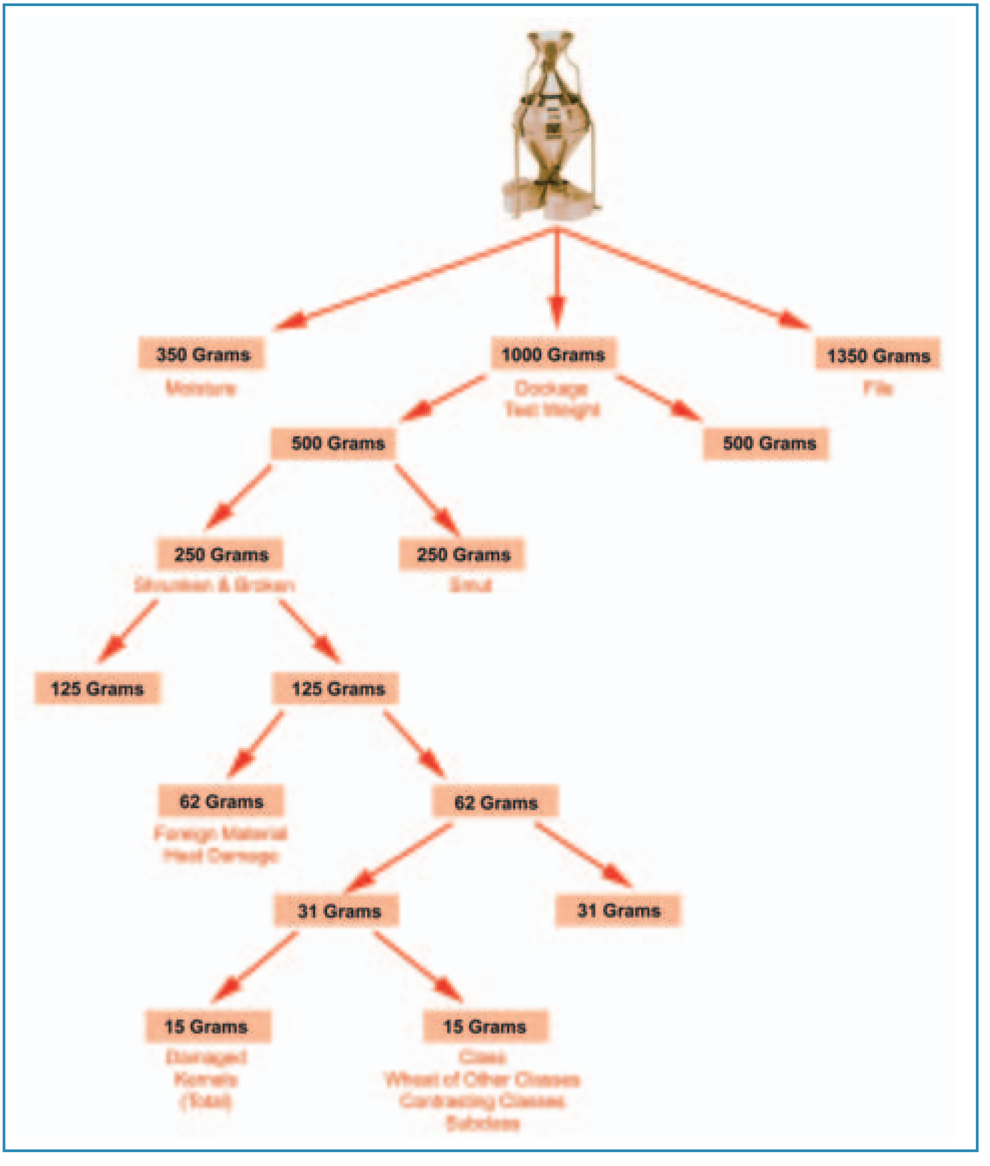


Fig. 13: Processing the working wheat sample
(courtesy of USDA-GIPSA – Grain Inspection, Packers and Stockyards Administration, Washington, D.C.)

5.6.2 Test Weight per Bushel

Following dockage removal, the test weight of the wheat is measured. Test weight per bushel is the weight of the grain required to fill a level Winchester bushel measure with a capacity of 2,150.42 cubic inches (35.24 L). The factor "test weight per bushel" is determined using an approved apparatus, which has a kettle capacity of one dry quart (1.101 L). This determination is made on the basis of 1,350 g of wheat cut from the representative sample using a Boerner Divider. To determine test weight, the work sample is poured into the closed hopper centred over the kettle. The valve is quickly opened to

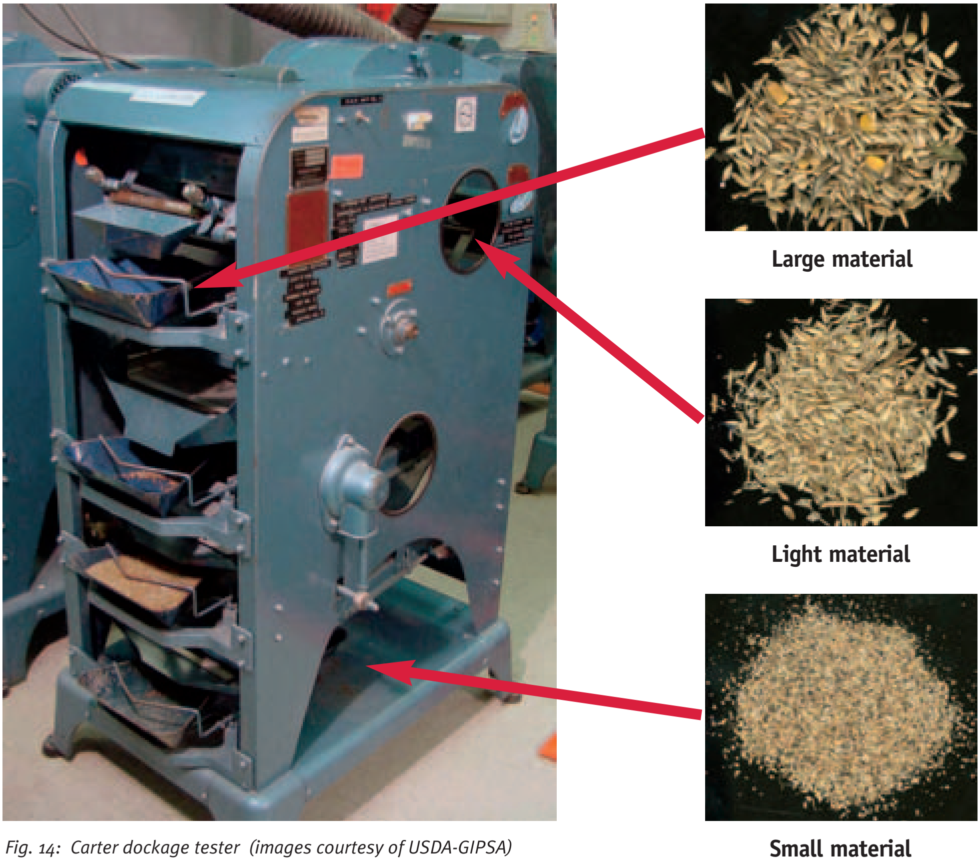
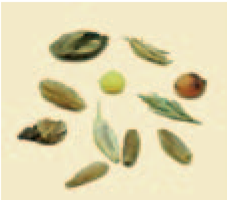
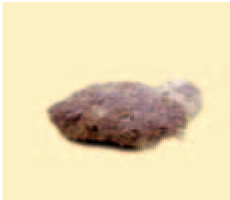


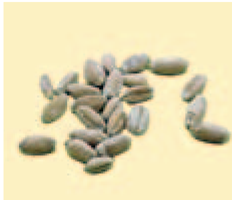
Fig. 14: Carter dockage tester (images courtesy of USDA-GIPSA)

allow the grain to fill the kettle. A standard stroker held in both hands with the flat sides in a vertical position is used to remove the excess grain from the top of the kettle with three full-length zigzag movements. The kettle is carefully placed on the scale platform. The weight is read by an electronic scale that converts the gram weight to either pounds per bushel or kg per hectolitre (Fig. 15). Test weight per bushel is a grading factor and will therefore influence the numerical grade of a wheat sample. In the U.S. it is generally expressed in pounds per Winchester bushel, but upon request it can be converted and reported in kg per hectolitre.

Fig. 15: Conducting a measurement of test weight (courtesy of USDA-GIPSA)

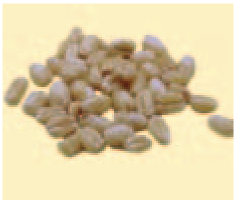

A - Foreign Material


B - Rodent excreta

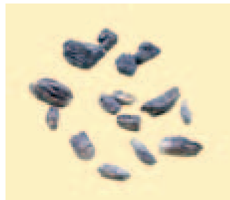

C - Foreign substance

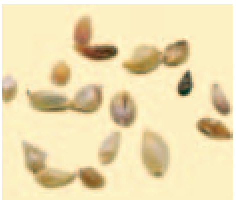

D - Stones

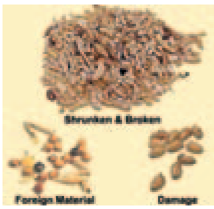

E - Crotolaria


F - Treated

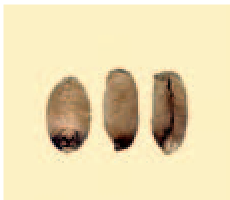

G - Smut

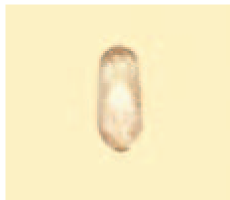

H - Ergot

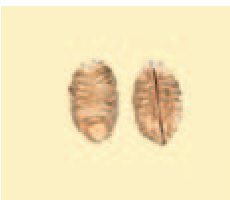

I - Garlic

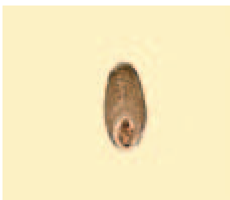


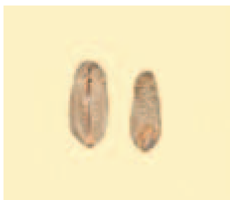
J - Total defects

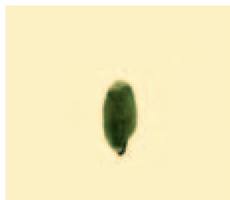

K - Black tip (3 degrees)


L - Blight or scab damage

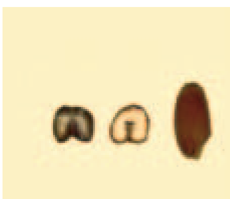

M - Frost damage (blistered)

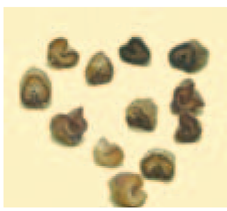

N - Germ damage (sick)


O - Germ damage (mould)


P - Green damage (immature)


Q - Heat damaged Durum


R - Heat damage, other than Durum


S - Heat damage

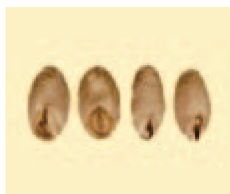
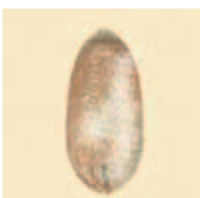
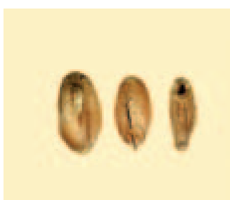
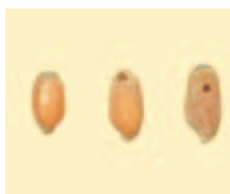

T - Sprout damage

Fig. 16: Sample and special grade factors (images courtesy of USDA-GIPSA)


U - Mould-like substance


V - Other damage


W - Insect-bored

5.6.3 Examining for Sample Grade Factors

Sample grade factors are f.i. animal filth, glass, stones, toxic seeds and unknown foreign substances. Special grade factors include ergot, smut, garlic, and treated seed (Fig. 16).

5.6.4 Examining for Special Grades

Special grades are provided to emphasize special qualities or conditions affecting the value of wheat and are added to, and made a part of, the grade designation. There are six special grades in wheat. Definitions and examples of the designations for special grades in wheat include:

Ergoty Wheat
Wheat that contains more than 0.05% of ergot.

Garlicky Wheat
Wheat that contains more than two green garlic bulblets or an equivalent quantity of dry or partly dry bulblets in a 1,000 g portion.

Infested Wheat
Wheat that is infested with live weevils or other live insects injurious to stored grain.

Light Smutty Wheat
Wheat that has an unmistakable odour of smut or which contains, in a 250 g portion, smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to 5 smut balls, but not in excess of a quantity equal to 30 smut balls of average size.

Smutty Wheat
Wheat that contains, in a 250 g portion, smut balls, portions of smut balls, or spores of smut in excess of a quantity equal to 30 smut balls of average size.

Treated Wheat
Wheat that has been scoured, limed, washed, sulphured, 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.
Special grades do not affect the numerical or sample grade designation.

5.6.5 Shrunken and Broken Kernels

At this point, all tests required to be performed prior to the removal of dockage have been made and the percentage of dockage has been determined. The sample has also been test-weighed and examined for certain sample grade and special grade factors. Now the work portion is ready to be divided into fractional portions for other determinations required after the removal of dockage. When testing wheat for shrunken and broken kernels, cut out a 250 g portion for shrunken & broken (SHBN) using the Boerner divider. SHBN kernels consist of all matter that passes through a 0.064 × 3/8 oblong-hole sieve after sieving using either the "Mechanical Sieving Method" or the "Hand Sieving Method". Mechanical sieving is preferred to the hand-sieving method because the results are more uniform and accurate in counting the number of strokes. All material that passes through the sieve is considered shrunken and broken kernels. Return the material lodged in the perforations to the wheat that has remained on top of the sieve. To remove the lodged material from the perforations, rub the sieve bottom gently. Tapping will warp the sieve and lead to inaccurate results in future determinations. At this point, the percentage of Shrunken and Broken has been determined. The material is weighed to the nearest tenth percent and recorded on the grade certificate. Now the SHBN-free portion is ready to be divided into fractional portions for other determinations required after the removal of SHBN.

5.6.6 Foreign Material

Foreign material or FM consists of all matter other than wheat that remains in the sample after the removal of dockage and shrunken and broken kernels (Fig. 16A). Determine foreign material on a dockage-free and shrunken-and-broken-free portion of 50 g. Other grains including oat groats, hull-less oats, glumes on threshed or unthreshed kernels, and all matter other than wheat are considered foreign material and removed from the portion. Remove the glumes from the kernels of wheat and add to the foreign material. The foreign material is expressed as a percentage by weight of the total sample. Record the percentage of foreign material on the certificate to the nearest tenth percent.

5.6.7 Damaged Kernels

Determine damaged kernels on a dockage-free and shrunken-and-broken-free portion of 15 g. Damaged Kernels Total or DKT is 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, mould-damaged, sprout-damaged, or otherwise materially damaged. In general, a kernel of wheat and/or kernels of other grains are considered damaged for inspection and grading purposes only when the damage is distinctly apparent and of such character as to be recognized as damaged for commercial purposes (Fig. 16).

Black Tip Damaged Kernels

Kernels affected by black tip fungus to the extent that the discoloration (fungus growth) extends beyond the germ and continues around at least one cheek and into the crease are considered damaged. All conditions MUST be met to be considered damage. The illustration shows, from left to right (Fig. 16K):
Kernel 1: The minimum degree of discoloration and amount of coverage required on the germ.
Kernel 2: The minimum degree of discoloration required in the "continuous band" that extends around the cheek. The width of the band is irrelevant.
Kernel 3: The minimum degree of discoloration required extends into the crease. The amount of discoloration (area of coverage) is immaterial.

Blight or Scab Damaged Kernels

Kernels with a dull, lifeless and chalky appearance resulting from disease are considered damaged. The germ and crease may also have a mouldy appearance. The illustration (Fig. 16L) shows a kernel affected by scab to the extent that it has a dull, lifeless, chalky appearance (not a natural wheat colour). Such kernels are scab-damaged without further examination.

Frost Damaged (Blistered) Kernels

Kernels that have blisters due to frost are considered damaged. The illustration (Fig. 16M) shows kernels with distinct frost blisters extending around the back of the kernel and into the crease.

Germ Damaged (Sick) Kernels

Kernels damaged as a result of microbial activity but not materially discoloured are considered damaged (Fig. 16N). Sick kernels should be scraped very carefully to avoid the loss of discoloration and/or "popping" or removal of the germ. Kernels and pieces of wheat with discoloured germs that are as dark as, or darker than, shown are to be considered damaged.

Germ Damaged (Mouldy) Kernels

Kernels which have mould in the germ are considered damaged. The bran coat covering the germ should be removed carefully, as scraping the bran coat too deep might remove the mould. Fig. 16O shows a kernel of wheat with a mouldy germ.

Green Damaged (Immature)

Kernels that are of an intense green (immature) and without any yellow appearance are considered damaged. Fig. 16P shows kernels that are green (immature) in colour. The green colour must meet the minimum intensity shown on BOTH sides of the kernel. Also there should be no yellow cast showing through the green.

Heat Damaged – Durum

Kernels materially discoloured and damaged by microbial activity are considered damaged. It is necessary, in most cases, to cut the kernels and make a cross-section analysis to determine whether the colour is reddish-brown, mahogany, or creamy. Fig. 16Q shows:
Kernel 1: An example of a kernel that should be cross-sectioned to determine whether it meets the minimum discoloration requirements depicted by Kernels 2 and 3.
Kernel 2: The degree of discoloration required in a cross-sectioned vitreous kernel.
Kernel 3: The minimum discoloration (cream)

required in a cross-sectioned non-vitreous (chalky) kernel to be considered heat damaged.

Heat Damaged – Other than Durum

Kernels materially discoloured and damaged by microbial activity are considered damaged. It is necessary, in most cases, to cut the kernels and make a cross-section analysis to determine whether the colour is reddish-brown, mahogany, or creamy. Fig. 16R shows:
Kernel 1: An example of a kernel that should be cross-sectioned to determine whether it meets the minimum discoloration requirements depicted by Kernels 2 and 3.
Kernel 2: The degree of discoloration required in a cross-sectioned vitreous kernel.
Kernel 3: The minimum discoloration (cream) required in a cross-sectioned non-vitreous (chalky) kernel to be considered heat damaged.

Sprout Damaged

Kernels with the germ end broken open from germination exhibiting sprout or from which the sprouts have been broken off are considered damaged. Fig. 16T shows, 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. Sprout sockets typically have bran around the perimeter of the germ that resembles a "horse collar".
Kernel 3: The germ cover is broken open with a sprout showing at the bottom. Notice that the sprout flares out towards the bottom of the germ area.
Kernel 4: The germ cover is broken open with a sprout showing at the top. The sprout has lifted upward leaving a spade between the sprout and germ cavity.

Mould-Like Substance

Whole kernels of wheat that are 50% or more covered and pieces of kernels that are discoloured and covered with a mould-like substance are considered damaged.

Fig. 16U shows mould or a mould-like substance on a wheat kernel.

Other Damage

Kernels with cracks, breaks or chews and which contain mould or fungus are considered damaged. Fig. 16V shows, from left to right:
Kernel 1: Broken kernel containing mould.
Kernel 2: Split bran coat containing mould.
Kernel 3: Insect-chewed kernel containing mould.

Insect-Bored

Kernels that have been bored or tunnelled by insects are considered damaged. Fig. 16W shows from left to right:
Kernel 1: Kernel that has been tunnelled.
Kernels 2 &3: Kernels that have been bored.

5.6.8 Total Defects

Total Defects is the sum of 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. Determine defects by the sum of damaged kernels, foreign material, and shrunken and broken kernels. A percentage for defects cannot be shown if only one or two of the factors defined as defects have been determined. However, if one or two factors are determined and their sum would change the numerical grade, or come close to changing the grade, determine the other factor and record the percentage of defects (Fig. 16J). Record the percentage of defects on the certificate to the nearest tenth percent. If the percentages for damaged kernels, shrunken and broken kernels and foreign material are added together and the total exceeds one hundred percent, adjust the percentage of defects by adjusting the damaged kernels (total).

5.7 Evaluation Process – Non Grade Factors

In addition to grading standards identified by governmental regulators there are often other quality measures imposed on the grain trade and millers. Tab. 11 presents a listing of non-grade evaluation criteria used for the various wheat classes. Additional flour, dough and baked or process product measurements are presented in Tab. 12 to Tab. 14. These additional factors should be considered when making wheat purchase decisions, and factors of most significance should be included in a purchase contract along with the class and grade criteria. North American milling companies conduct annual crop surveys internally or utilize outside services to evaluate the crop during the harvest. This allows their wheat buyers to identify the growing locations most closely meeting the customer's requirement. Each year's harvest produces a wheat crop with different characteristics that must be accommodated. The nature of wheat production and the commodity business often causes the wheat flour specifications used by bakers to change, depending on the crop year. Another point to consider is that a wide array of tests must be used to make an accurate evaluation. No single test has the ability to predict milling, flour, semolina or finished-product characteristics. Finally, there is the issue of the "sweat". Sweat is that period of time following harvest during which wheat milling and baking properties are less than desirable. Since wheat is a living, respiring biological material the concept of the "sweat" should be no more of a surprise than the concept of ageing beef, wine or cheese to improve flavour, aroma or texture. Once this time has

Wheat Classes

AD – Amber Durum
DNS – Dark Northern Spring
HAD – Hard Amber Durum
HRS – Hard Red Spring wheat
HRW – Hard Red Winter wheat
HWW – Hard White (Winter) wheat
SRW – Soft Red Winter wheat
SW – Soft White wheat

Tab. 11: Wheat non-grade characteristics from 2004 [a, 6]

Test		HRW	HRS	HWW	SRW	SW	Durum
Dockage	%	0.7	1.2	0.9	0.6	0.6	1.5
Moisture	%	11.6	11.9	9.6	13.0	9.2	11.5
Protein							
12% m.b.	%	12.2	14.5	12.2	10.2	10.2	14.2
0% m.b.	%	13.8	16.5	13.9	11.6	11.6	16.1
Ash							
12% m.b.	%	1.55	1.66	1.52	1.56	1.39	1.64
0% m.b.	%	1.80	1.93	1.77	1.82	1.62	1.91
1000 kernel weight	g	28.6	29.5	32.0	32.4	34.2	36.1
Kernel size, lg/md/sm[b]	%	53/45/02	53/39/8	70/29/01	82/17/01	87/13/00[c]	52/40/08
Single kernel							
Hardness	I	73.7	82.1	69.3	23.2	31.8	-
Weight	mg	29.4	30.4	34.3	32.6	35.2	-
Diameter	mm	2.26	2.31	2.44	2.31	2.48	-
Sedimentation	mL	40.0	54.3	17.5	14.3	17.9	46
Falling Number	s	397	363	427	341	347	301

[a] Data courtesy of U.S. Wheat Associates, Washington, D.C. [b] Large, medium and small kernels [c] 2004 "All"

[6] 2004 U.S. Wheat Associates Crop Report: HRW 5-year average midwestern harvest data composite, HRS 5-year average harvest data composite, HWW harvest data pacific northwest medium protein, SRW 5-year average harvest composite, SW 5-year average pacific northwest harvest data, Durum 5-year great plains average harvest data.

Tab. 12: Wheat flour and semolina characteristics from 2004 [a, 6]

Test		HRW	HRS	HWW	SRW	SW	Durum
Extraction rate, total	%	70.3	68.9	69.3	69.9	66.7	70.2
Color							
L*		92.3	90.5	91.8	93.4	92.5	84.4
a*		-3.3	-1.4	-2.8	-3.4	-2.7	-2.7
b*		9.5	9.4	8.4	8.1	7.2	27.7
Protein							
14% m.b.	%	10.8	13.3	10.7	8.5	8.5	13.1
0% m.b.	%	12.6	15.4	12.4	9.9	9.9	15.3
Ash							
14% m.b.	%	0.49	0.45	0.40	0.44	0.36	0.69
0% m.b.	%	0.57	0.53	0.47	0.51	0.42	0.81
Wet gluten	%	28.4	35.9	29.5	22.3	22.7	37.2
Falling Number	s	415	393	443	336	345	-
Amylograph viscosity							
65 g	BU	643	599	770	489	566	-
100 g	BU	-	2149	-	-	-	-
Starch damage	%	8.6	-	5.8	4.4	-	-
Specks	no/10 in^2	-	-	-	-	-	23

[a] *Data courtesy of U.S. Wheat Associates, Washington, D.C.*

Tab. 13: Wheat flour and semolina dough characteristics from 2004 [a, 6]

Test		HRW	HRS	HWW	SRW	SW	Durum
Farinograph							
Peak time	min	5.8	11.6	2.4	1.7	1.5	-
Stability	min	10.8	20.5	48.7	3.2	2.7	-
Absorption	%	59.5	64.9	57.0	52.6	50.3	-
Classification		-	6.6	-	-	-	-
Alveograph							
P	mm	94	96	110	35	44	35
L	mm	90	113	84	105	100	105
W	$J \cdot 10^{-4}$	290	385	334	88	113	82
Extensograph							
Resistance	EU	-	512	640	-	264	-
Extension	cm	-	23.2	12.6	-	15.3	-
Area	cm^2	-	148	108	-	59	-
Mixograph classification		-	-	-	-	-	6

[a] *Data courtesy of U.S. Wheat Associates, Washington, D.C.*

Tab. 14: Wheat flour baking or semolina processing characteristics from 2004 [a, 6]

Test		Unit	HRW	HRS	HWW	SRW	SW	Durum
Bread								
Crumb grain			6.9	-	-	5.8	-	-
Crumb texture			7.3	-	-	5.9	-	-
Loaf volume		mL	839	-	-	750	-	-
Sponge cake	Volume	mL	-	-	-	-	1163	-
	Score		-	-	-	-	52	-
Cookie diameter		cm	-	-	-	-	8.4	-
	Spread ratio		-	-	-	8.4	-	-
Baking evaluation								
Absorption		%	-	63.4	62.1	-	-	-
Crumb grain and texture (1-10)			-	8.2	5.8	-	-	-
Loaf volume		cm^3	-	1062	759	-	-	-
Spaghetti processing data								
Colour score		-	-	-	-	-	9.0	
Cooked weight		g	-	-	-	-	-	31.4
Cooking loss		%	-	-	-	-	-	5.8
Cooked firmness		g/cm	-	-	-	-	-	6.1
Noodle making quality								
Colour (0 h)		L*	-	-	84.1	-	-	-
		a*	-	-	-1.0	-	-	-
		b*	-	-	20.1	-	-	-
Colour (24 h)		L*	-	-	76.4	-	-	-
		a*	-	-	-0.7	-	-	-
		b*	-	-	26.3	-	-	-
Cooking yield		%	-	-	129	-	-	-
Sensory colour stability score			-	-	7.7	-	-	-
Instrumental texture								
Firmness		g	-	-	1184	-	-	-
Springiness		g	-	-	97.6	-	-	-
Cohesiveness			-	-	0.66	-	-	-
Chewiness		g	-	-	762	-	-	-

[a] *Data courtesy of U.S. Wheat Associates, Washington, D.C.*

passed, milling, baking and processing properties appear more "normal". As the transition from old crop to new crop carries some economic incentive (new crop grain generally costs less), most millers and their customers agree to a managed introduction of the new crop into the mill mix to minimize any negative effect of this biological change.

5.7.1 Moisture

The Grain Analysis Computer Model 2100 (GAC, 2100), manufactured by Dickey-John Corporation, Auburn, Illinois, is the official moisture meter for the national inspection and weighing system. The GAC 2100 is calibrated to the USDA air-oven method (1 h at 130 °C).

5.7.2 Protein

53 The standard Kjeldahl procedure for nitrogen determination used to measure protein employs a nitrogen conversion factor of N × 5.7 for wheat and flour. The exception is for feed wheat, which is determined using an N × 6.25 factor. Protein is expressed as a percentage of the sample on a 12.0% m.b. for wheat and 14.0% m.b. for flour. Protein content is a very important consideration when assessing the suitability of wheat for different end products.

FGIS uses near-infrared transmittance (NIRT) spectroscopy to determine protein for official inspections. FGIS adopted the Combustion Nitrogen Analyzer in 1994 as the standard reference method for determining wheat protein because it provides accurate and consistent results with less chemical exposure to the inspectors and uses no hazardous chemicals, and the analysis time for the Combustion Nitrogen Analyzer is shorter. FGIS' wheat protein laboratory is certified ISO 9002 compliant by the International Standards Organization. All field NIRTs are calibrated to the standard protein reference method, the Combustion Nitrogen Analyzer, to ensure the accuracy of the results. Each NIRT instrument is checked for accuracy daily using a set of five standard reference samples for each class of wheat. If the daily average of the results on the standard reference samples differs by more than +/- 0.10%, the instrument is adjusted and rechecked before use. The goal is to have a daily tolerance within +/- 0.05% difference. The same set of standard reference samples is used throughout the FGIS national system for checking official NIR instruments. The Combustion Nitrogen Analyzer consists of a computer-controlled, closed system, combustion process, and a thermal conductivity detector. Protein is usually reported on the 12.0% m.b. Upon request in the sales contract, FGIS will report protein on an alternate moisture basis, in addition to the 12.0% m.b. The buyer can specify protein in the following ways:

1. Ordinary protein: any protein level can be loaded,
2. Average protein: a weighted or mathematical average of the sublots with no limit on sublot variability,
3. Minimum or maximum protein with a weighted or mathematical average of sublots where Cu-Sum[7] applies with limits on sublot variability, or
4. Modified minimum or maximum protein: sublots are weighted or mathematically averaged with a reduced Cu-Sum breakpoint. For example, a request for Northern Spring wheat, minimum 14.0% protein, with no sublot below 13.8%; or Soft White wheat, maximum 9.0% protein, with no sublot above 9.2%.

Abbreviations

DHV	–	*Dark, Hard and Vitreous kernel content*
DKT	–	*Damaged Kernels Total*
FM	–	*Foreign Material*
N	–	*Nitrogen*
NIR	–	*Near-Infrared spectrometry*
NIRT	–	*Near-Infrared Transmittance spectrometry*
PSI	–	*Particle Size Index*
SHBN	–	*Shrunken and Broken*
SKCS	–	*Single Kernel Characterization System*

[7] *A method of tracking variability across a large lot of grain – see Anon., 1990.*

5.7.3 Wheat Ash

29 The ash content of wheat and flour is the mineral residue remaining after incineration of the sample. Ash is determined according to standard AACC methods and is expressed as a percentage of the sample on an 11.0% m.b. for wheat and a 14.0% m.b. for flour. Flour ash is related to the milling extraction and is used both as a measure of flour grade and as an indication of milling efficiency.

5.7.4 Thousand Kernel Weight

Thousand-kernel weight is the weight in grams of 1,000 kernels of grain and provides a measure of grain size and density. The thousand kernel weight is independent of some factors which influence the measurement of bulk density, so it is sometimes preferred to test weight as a measure of grain quality.

5.7.5 Grain Hardness

Grain hardness is determined by measuring wheat meal granularity, expressed as the Particle Size Index (PSI). In this test, 10 g of wheat are ground in a Falling Number KT30 mill set at its finest setting. The PSI is expressed as the percentage of flour produced after 5 min sieving over a Number 15 nylon screen using a Simon Rotary sifter. Grain hardness can also be measured with a new system offered by Perten Instruments called a Single Kernel Characterization System (SKCS). The Perten Single Kernel Characterization System 4100 (SKCS 4100) provides rapid (3 min) and objective measurement of hardness classification and determin-ation of uniformity in grain. Using measurements made on 300 individual kernels in a sample, the SKCS 4100 determines individual kernel hardness, weight, diameter and moisture. Results are obtained as mean values and standard deviations for each of the four parameters. Distributions of kernel data are illustrated in histograms. Further the SKCS 4100 classifies the wheat according to the Hardness Index. Additional characteristics, such as tempering status and milling performance, can optionally be predicted.

The visual and internal quality characteristics of individual kernels of grain differ, for example between different varieties, soil types and weather conditions; the variations show, for example, in kernel hardness, moisture content, diameter and kernel weight. Within a specific load of wheat the miller wants the grain to be as uniform as possible to obtain the optimal milling result. To accomplish this, the individual kernels need to be as uniform as possible in terms of weight, diameter, hardness, moisture etc.

5.7.6 Falling Number

The Falling Number System measures the effected α-amylase enzyme activity in grain meal to detect sprout damage and guarantee the soundness of traded grain. The principle of the Falling Number method is to use the starch contained in the sample as a substrate. The starch is rapidly gelatinized when the test tube with the sample suspended in water is inserted into a boiling water bath. Subsequently the α-amylase enzyme in the sample starts to liquefy the starch, and the speed of liquefaction is dependant on the α-amylase activity. A high level of activity causes faster liquefaction, which results in a lower Falling Number result and vice versa. The Falling Number method is used at grain intake for segregation and classification of the grain and in the flour mill for monitoring incoming grain and control of blended grain. It is also used as a basic quality parameter when grain is traded. The

Organizations

AACC	–	*American Association of Cereal Chemists, St. Paul, MN, USA*
FGIS	–	*Federal Grain Inspection Services*
GIPSA	–	*Grain Inspection, Packers and Stockyards Administration, Washington, D.C.*
ICC	–	*International Association for Cereal Science and Technology, Vienna, Austria, formerly International Association for Cereal Chemistry*
ISO	–	*International Organization for Standardization, Geneva, Switzerland*
USDA	–	*United States Department of Agriculture*

Falling Number system offers a rapid (approx. 10 min) way to determine the quality of the starch and α-amylase interaction. When a Falling Number test is to be performed on whole grain a hammer type laboratory mill is used to grind the grain.

5.7.7 Screenings

The wheat sample is sieved over a 2 mm slotted screen using 40 shakes of the sieve. "Screenings" is the total material passing through the screen and is expressed as a percentage by weight of the total sample.

5.7.8 Experimental Milling Evaluation

Wheat is conditioned for 24 h following the addition of an appropriate amount of water, as determined by the natural grain moisture and the PSI value. Test milling is then conducted on a Bühler laboratory mill using appropriate roller mill settings and sieve covers. The flour is usually obtained by combining all flour streams and the "straight run" flour extraction is reported. For noodle quality assessment, excluding a calculated quantity of reduction flour from the final product produces 60% extraction flour. Flour extractions are calculated on a total milled products basis.

5.8 Evaluation Process – Evaluating Flour, Dough and End Products

5.8.1 Determining Flour Quality

Flour quality means different things to different users with different end goals. Typically, some conformance to a preset standard of functionality is used to describe a flour's "quality". This standard of functionality is often based on the experience of the user in correlating a test or group of tests to his particular product. Ultimately, flour quality is defined by the flour's ability to make the desired end product to the expectations of the user on a consistent basis. Because quality flour is imperative for the production of quality baked goods, flour functionality is controlled through careful wheat selection, mill process control, and analytical testing.

Flour strength is often used to describe the quality of flour, "strength" being the flour's ability to withstand mixing, absorb water, or perform satisfactorily in an end user's baking process. It seems that there are as many ways to describe flour strength as there are baked products. In general strength relates to protein, both in the quantity available and the quality of that which is available. Protein quantity, related to the amount of total organic nitrogen, is one of the first evaluations made in determining a flour specification and – more importantly for the miller – a wheat purchase specification. But protein quantity alone is not sufficient to describe and ensure the usefulness of wheat flour. Certain other physical tests have been developed to assess a flour's usefulness related to its protein quality. These tests are often performed on flour-water doughs. Dough is defined as wheat flour moistened with water or some other liquid ingredient at a specified ratio and then blended or mixed by mechanical means. Evaluating wheat through the flour made from it begins with three basic tests: moisture, protein and ash.

5.8.2 Flour Protein

Protein is determined as nitrogen, with a factor of N × 5.7, 14% m.b. (see also chapter 5.7.2 and 12.6).

5.8.3 Flour Ash

Ash is determined on a 4 g sample in a silica dish incinerated overnight at 585 °C. After cooling, the dish and ash are weighed, the ash brushed out, the dish reweighed, and the weight of ash determined by the difference. The results are reported as a percentage. The following physical flour tests are applied beyond just moisture, protein and ash:

5.8.4 The Falling Number System

The principle of the Falling Number method is the same as that used to test wheat meal. The Falling Number method is used in the flour mill for monitoring and controlling the blending of flours and for calculation and control of malt or fungal enzyme addition. It is also used as a basic quality parameter when flour is traded. In bread, too much α-amylase activity will cause wet, sticky crumb with large voids in the loaf, and too little will cause dry, crumbled bread crumb and high loaf density.

5.8.5 Brabender Amylograph

The Amylograph performs a measurement based on the viscosity of a flour-water suspension. This test device uses a standardized heating cycle to measure the rate and extent of change in the viscosity of the suspension over time. Swelling and gelatinization of the starch thickens the suspension and thereby raises its viscosity. Enzyme activity also increases during this process. The enzymes break down the gelatinizing capability of some of the starch, which will ultimately lower the viscosity of the suspension. The increase and ultimate decrease in viscosity is measured and recorded by the Amylograph machine. This measurement can be used in much the same way as the Falling Number measurement in determining the requirement for additional enzymes to be added to the flour for optimum activity.

The new Micro ViscoAmyloGraph shown above evaluates starch or flour samples at a fraction of the standard requirements without neglecting the need for accuracy and reliability. Only 5 - 10 g of sample are needed for an evaluation. Total test time can be reduced by the elevated temperature rate increase (up to 10 °C/min). The new Micro ViscoAmyloGraph, following previous Brabender models, monitors and records actual stock temperature. Modern correlation software allows users to compare up to 15 different curves.

5.8.6 Physical Dough Tests

Common physical (rheological) dough tests used for determining flour quality include the Mixograph, Farinograph, Alveograph and Extensograph methods. In addition to standardized tests, many millers and bakers use specific baking tests as a way of comparing the functional characteristics of different flours. A detailed background of all methods is given by Weipert (chapter 13.1).
The Farinograph is generally described as a recording dough mixer. That is, it attempts to measure and report the mixing characteristics of a flour in a standard manner. Developed by Brabender around 1930, it has become the most recognized recording dough mixer in North America. Most of the flour mill laboratories in the U.S. rely on the Farinograph when evaluating wheat flour for use in breads. Fig. 17 shows representative examples of Farinograph records called Farinograms. The FarinographE is similar to the Farinograph, but the new model is a totally electronic instrument. The previous mechanical balance system has been replaced by a sensitive, modern electronic system for torque measurement. A serial port transfers the measured data to the evaluating computer. The zero point is automatically set by the measuring system. Choosing the correct mixer sets the sensitivity range: 10, 50, or 300-gram mixer. Modern software allows the creation of master curves to be stored for quality control purposes.

5.8.7 Baking / Product Evaluation Tests

Baking tests are also important methods of determining and ensuring quality for the commercial miller and baker. These tests often use loaf volume as the measure of flour strength. Balanced flour strength and adequate elasticity for oven expansion are critical in making quality bread products.

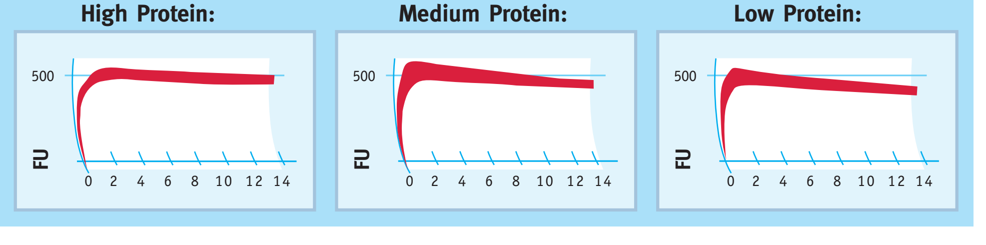


Fig. 17: Representative Hard Red Winter Farinograms from the U.S. Wheat Crop Quality Book 2004

5.9 U.S. Wheat Grades

Tab. 15 summarizes the grade requirements for wheat.
There are 5 wheat grades for good quality wheat. All other wheat, i.e. wheat that
– does not meet the requirements for grades U.S. Numbers 1, 2, 3, 4 or 5; or
– has a musty, sour, or commercially objectionable foreign odour (except smut or garlic odour); or
– is heating or otherwise of distinctly low quality, is classified U.S. sample grade.

Tab. 15: Grades and grade requirements for wheat

Grading Factors	Grades U.S. Numbers				
	1	2	3	4	5
	Minimum pound limits of				
Test weight per bushel					
Hard Red Spring wheat or White Club wheat	58	57	55	53	50
All other classes and subclasses	60	58	56	54	51
	Maximum percent limits of				
Defects					
Damaged kernels					
Heat (part of total)	0.2	0.2	0.5	1	3
Total	2	4	7	10	15
Foreign material	0.4	0.7	1.3	3	5
Shrunken and broken kernels	3	5	8	12	20
Total[a]	3	5	8	12	20
Wheat of other classes[b]					
Contrasting classes	1	2	3	10	10
Total[c]	3	5	10	10	10
Stones	0.1	0.1	0.1	0.1	0.1
	Maximum count limits of				
Other material					
Animal filth	1	1	1	1	1
Castor beans	1	1	1	1	1
Crotalaria seeds	2	2	2	2	2
Glass	0	0	0	0	0
Stones	3	3	3	3	3
Unknown foreign substance	3	3	3	3	3
Total[d]	4	4	4	4	4
Insect-damaged kernels in 100 g	31	31	31	31	31

[a] *Includes damaged kernels (total), foreign material, shrunken and broken kernels.*
[b] *Unclassed wheat of any grade may contain not more than 10.0% of wheat of other classes.*
[c] *Includes contrasting classes.*
[d] *Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substances.*

5.10 Milling Industry Overview

The U.S. Milling Industry has undergone dramatic change from any perspective, both from a historical and a current business view. North American milling is without question a competition-based market. It has been shaped and moulded by the economic forces created by the combined decisions of the consumers and producers of flour. In order to put these changes into a context to which we can all relate, a set of terms common to the U.S. market will be used to bring some clarity to this subject matter.

- **Annual Wheat Flour Production:**
  Total flour produced by all U.S. milling companies combined in one calendar year. Expressed in Cwt [8].
- **Daily Capacity:**
  The amount of flour capable of being produced by all U.S. mills in one 24-hour period. Expressed in Cwt (shown here in metric tonnes).
- **Operating Rate:**
  A percentage calculated by dividing the "Annual Wheat Flour Production" by the theoretical "Annual" 6-day capacity of the industry. Expressed as a percentage
- **Per Capita Consumption:**
  The amount in pounds of wheat flour consumed per person in the U.S. This includes all forms of wheat-based food products and is calculated on a disappearance basis. Expressed in lb per year.

Flour milling is clearly one of the world's oldest industries, for the extraction of endosperm from wheat as a source of food was one of mankind's first halting steps towards civilization. In America flour milling is among the oldest industries; in fact the first flour mill was established in Virginia in 1621, or just 14 years after the settlement of Jamestown. In the 18th and 19th centuries, as the U.S. grew and moved west, new flour mills were built as virgin lands were cultivated and began producing large crops of wheat. As the people moved west, so did the production of wheat and the milling of flour. Towards the end of the nineteenth century, as wheat growing became established in the Great Plains, the mills in that area tended to become larger, and those plants remained in operation well after the westward migration of people spilled over the Rocky Mountains onto the West Coast. Even as the westward migration to California, Oregon and Washington of the nineteenth century turned into the flood of the twentieth, two of the three largest wheat flour milling states were in the heart of the traditional wheat growing region – Kansas, which ranks number one and Minnesota, which is number three (California has recently replaced New York as number two; Anon., 1998).

Not only is flour milling one of the oldest industries in the United States; it has also been one of the largest industries. In fact in 1900 flour milling was the largest industrial classification in the United States, with some thousands of small, mostly privately owned mills. This is no longer the case. Today the number of mills has dropped to less than 200, most of these being large mills. The number of companies owning mills has compressed even more dramatically. If we look at the current status of the U.S. milling industry we see there are at least four trends of some significance.
The first trend is the reduction of companies currently milling wheat into flour in the U.S. (Tab. 16).
The milling industry (as well as world enterprise in general) is confronted by relentless adjustment. Each day the industry commits itself to a course of action based on the best knowledge and judgment available, then waits for history to determine who was right and who was not. Economic forces are inexorable. What has been experienced will continue to be experienced in terms of consolidation. This scenario has been played out in industry after industry as they become mature and economics of scale become relatively more important than innovation and product differentiation in the economic return equation.

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[8] ***1.*** *A unit of weight in the U.S. Customary System equal to 100 pounds (45.36 kg).*
Also called ***cental****, or* ***short hundertweight****.*
2. *A unit of weight in the British Imperial System equal to 112 pounds (50.80 kg). Also called* ***quintal****.*

Tab. 16: U.S. milling industry changes

		1974	1980	1993	2003
Companies in operation		161	140	95	84
Company average capacity[a]	t/d	279	347	592	817
Mills in operation		280	255	208	177
Mills per company		1.73	1.82	2.19	2.11
Average location capacity[a]	t/d	160	191	270	387
Total capacity[a]	**t/d**	**44,838**	**48,662**	**56,274**	**71,079**

[a] *Flour production*

One of the clear effects of competition-based change is that there are winners and losers. In U.S. milling, maybe "winner" doesn't describe the existing milling companies as well as the term "survivor". As is true in all business, we must look at a longer view to understand if a current "survivor" is a true winner or simply the next market-place victim. History is shouting that the number of milling companies in the United States is in decline. Current economics seem to support a continuation of that decline. As of this writing there are approximately 194 wheat flourmills operated by about 85 milling companies (Anon., 2000).

The second trend, which is tied to the first, is the reduction in the number of operating mills in the United States (Tab. 16).

The message of Tab. 16 is that the U.S. demand for flour compared to the available supply is limiting the financial return for milling companies. This earnings pressure is causing milling companies interested in remaining in the business to look for growth through acquisition. The goal of the acquisition is to increase sales volume without increasing the corporate infrastructure required to operate the company, thus allowing the remaining company to take advantage of the increased scale through increased earnings.

Tab. 16 also shows the long-term change in the number of mills and in the average size of the remaining mills since 1974. It is interesting to note that average mill size has more than doubled while the number of milling locations has dropped to slightly more than half. Again, it appears that in order to produce an acceptable return for the company owners, a mill has had to increase the output of a location in a greater proportion to its fixed cost structure. Much like a company has had to add locations to increase its output in relation to its overall corporate size, the individual mill has had to increase its output in relation to the fixed operating costs of an individual location.

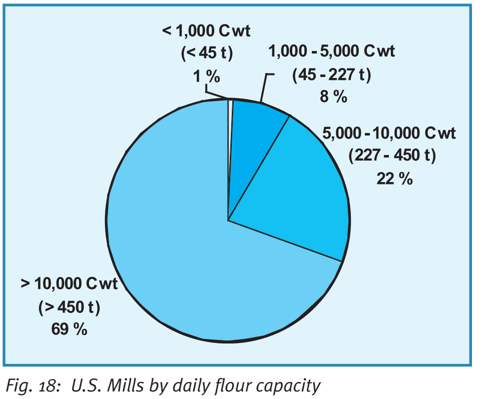

Fig. 18: U.S. Mills by daily flour capacity and market share (Anon., 2005)

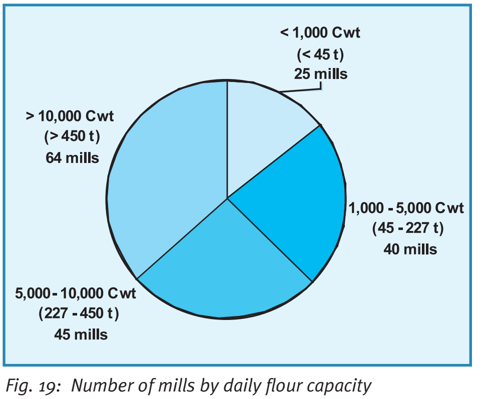

Fig. 19: Number of mills by daily flour capacity (Anon., 2005)

This third trend of increased mill size is understood better by comparing Fig. 18 and Fig. 19. These charts further break down the number of mills in operation and group them by overall size. While the average U.S. mill produces just over 380 t of flour per day, the reality is that the largest number of mills in the U.S. produces more than 450 t of flour per day. This further highlights the fact that mills have had to get bigger to maintain or improve their financial position. Finally, if we look at the amount of wheat ground by all mills within a size distribution we can see that as expected the largest mills also dominate the overall capacity of the country. In fact two thirds of all wheat is ground by one third of the mills.

Mills and milling companies positioned well geographically and strategically have survived to acquire those that have good geography but a poor strategy. Those with neither good geography nor good strategies are typically the mills abandoned.

The final trend is somewhat surprising. The U.S. industry has continued to grow in overall daily capacity. While consolidation has taken out numerous mills and milling companies, the opposite has happened with respect to the ability of the industry to produce flour (Fig. 20). This chart shows that there has been an upward trend in the capacity to produce flour in the U.S. for the last 6 years of the last decade. While this has been an exciting time of resurgence for the industry, the current condition is not one of widespread optimism. Part of the issue has to do with the amount of capacity added in the late 1990s. As many have said, the Western U.S. needed one new flour mill in 1999, but 4 milling companies built it.

Some focus should be given to the U.S. wheat flour demand. Several factors go together to create the overall demand for wheat flour in the United States.

- **Population**
- **Per Capita Consumption**
- **Dietary Perceptions**
- **Flour Use**

The demand for flour in the U.S comes from two major factors. The first is the U.S. population and the second is per capita consumption of wheat flour based products. Flour and wheat based imports, while important, have been largely flat over time and have been ignored in this analysis. Exports of U.S. flour have played an important role in the strength of the U.S.

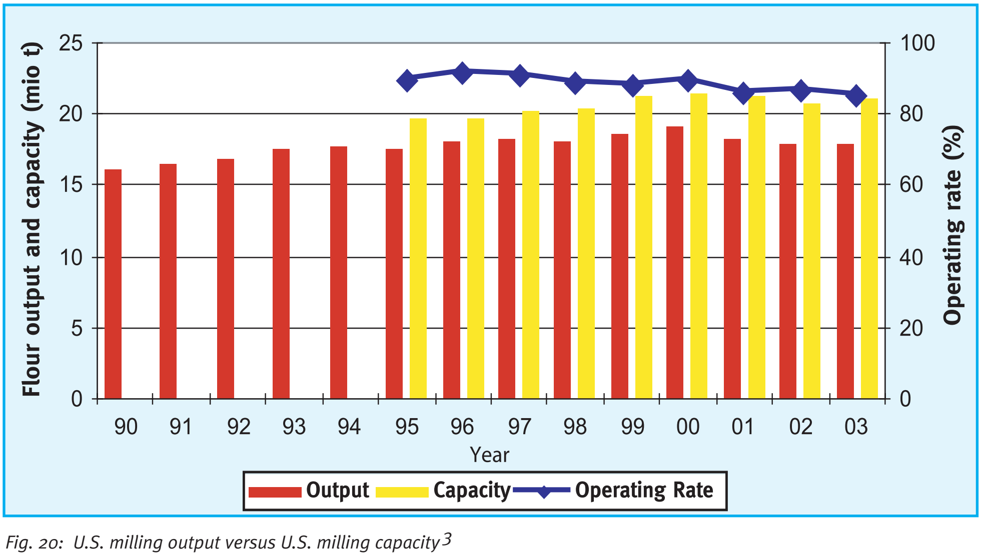

Fig. 20: U.S. milling output versus U.S. milling capacity [3]

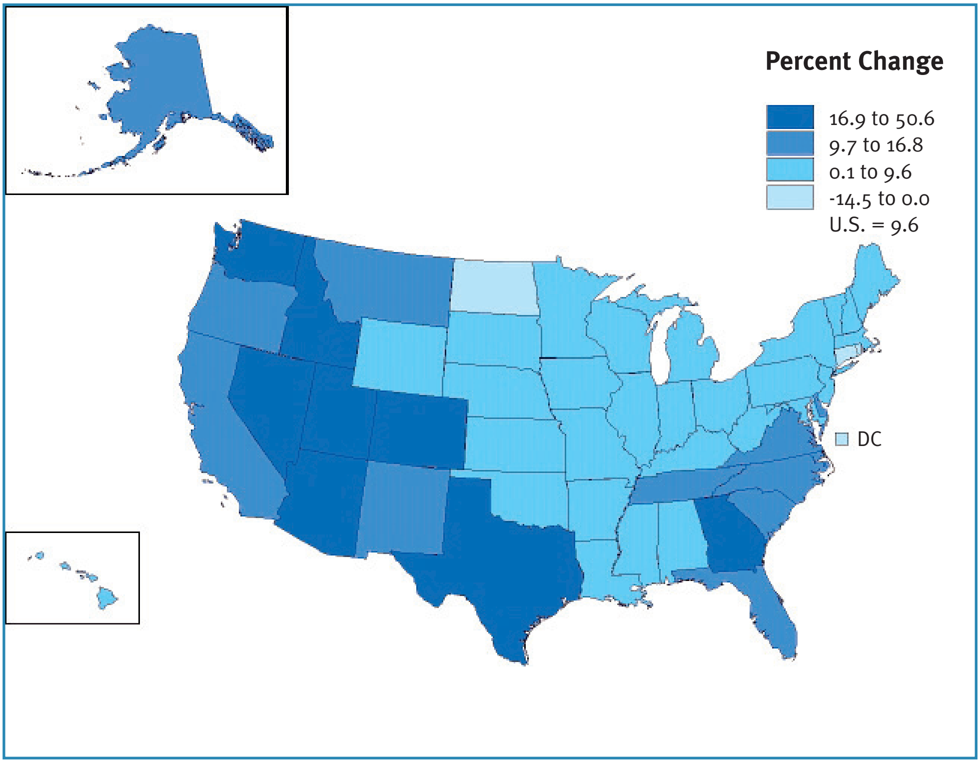

Fig. 21: Change in population for U.S. states 1990 to 1999 (source: U.S. Census Bureau)

industry; however, commercial exports are generally overshadowed by governmental policies and therefore are not a good indication of the U.S milling industry's world competitiveness. Exports, too, have been ignored as a part of the demand for U.S. flour and flour based products.

The U.S. population has grown at a fairly steady pace over the last 3 decades. The percentage, 13.2%, for the decade ending in 2000 has been both steady and predictable. The difficulty for millers is that while the population has grown nicely in total, it has not grown consistently for all regions. For instance, the U.S. population growth rates are highest in the West and South and the lowest in the Northeast and Midwest (Fig. 21).

The shift of population centres from North to South and East to West has had the impact of shifting flour demand away from some of the North Eastern and Midwestern mills towards mills able to send flour to the growing Western markets.

Per capita consumption is equally critical to a growing U.S. industry. Remember, in the U.S. we measure the amount of flour consumed in one year, not the wheat. In so doing we exclude the amount of wheat eaten by animals. The growth in per capita consumption of flour has been one of the real success stories in the U.S. food industry. U.S. flour consumption has grown by nearly 25% since 1964, and has fuelled the need for much of the milling capacity expansion. This growth in demand has come about due to a couple of factors. The primary reasons were that a favourable perception that "grain is healthy" was combined with an American population that began to eat on the go. Meaning that the meal is consumed away

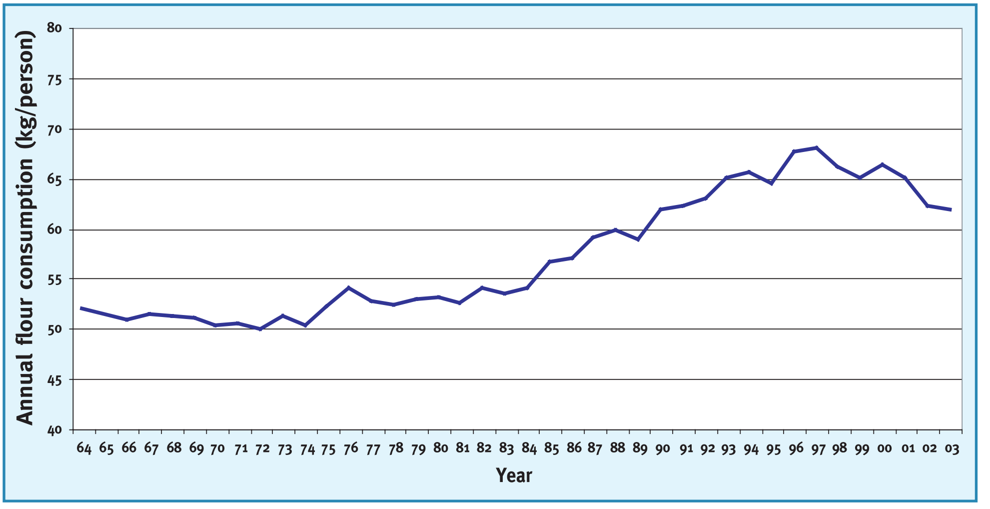

Fig. 22: U.S. flour consumption per capita by year[3]

from home, often in an automobile, making time and convenience extremely important. This has dramatically increased the use of wheat flour products used as "meal carriers". Buns for hamburgers and hot dogs; tortilla wraps for hand-held meals and sheeted bread products like pizza dominated the consumption growth of the last three decades. The "grain is healthy" viewpoint was further enhanced by the government's adoption of the food guide pyramid (page 28) that describes a healthy diet as being based upon foods made from grain.

One area of concern is the apparent levelling of this growth trend that appears to have taken place over the last couple of years (Fig. 22). Much of the concern lies in the unknown. No one is sure, but the speculation is that we may have reached a plateau of consumption in the U.S. Others more optimistic see this not as a plateau but as a slowing of the growth rate. In either case, the growth rate of domestic flour demand has slowed to near stagnation, equal to just that growth that has come from the increased population and government aid donations. This will continue to challenge the U.S. milling industry to make many tough decisions about capacity. The likely scenario is one of continued consolidation in the number of companies, and the abandonment of misplaced less strategic capacity. The U.S. milling industry is believed to be healthy economically when the industry operating rate exceeds 90%. Any reduction in demand or increase in supply in the near term could push the industry into another round of consolidation.

However, an end to the consolidation will come. Over time the remaining milling companies and mills will be less likely to overbuild capacity and repeat the cycle of oversupply and consolidation. This belief is based upon the assumption that with fewer companies making "capacity-balancing decisions", better decisions will result. These surviving companies, hurt economically in this recent period of capacity expansion, will be less likely to trigger another state of over capacity.

5.11 References

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