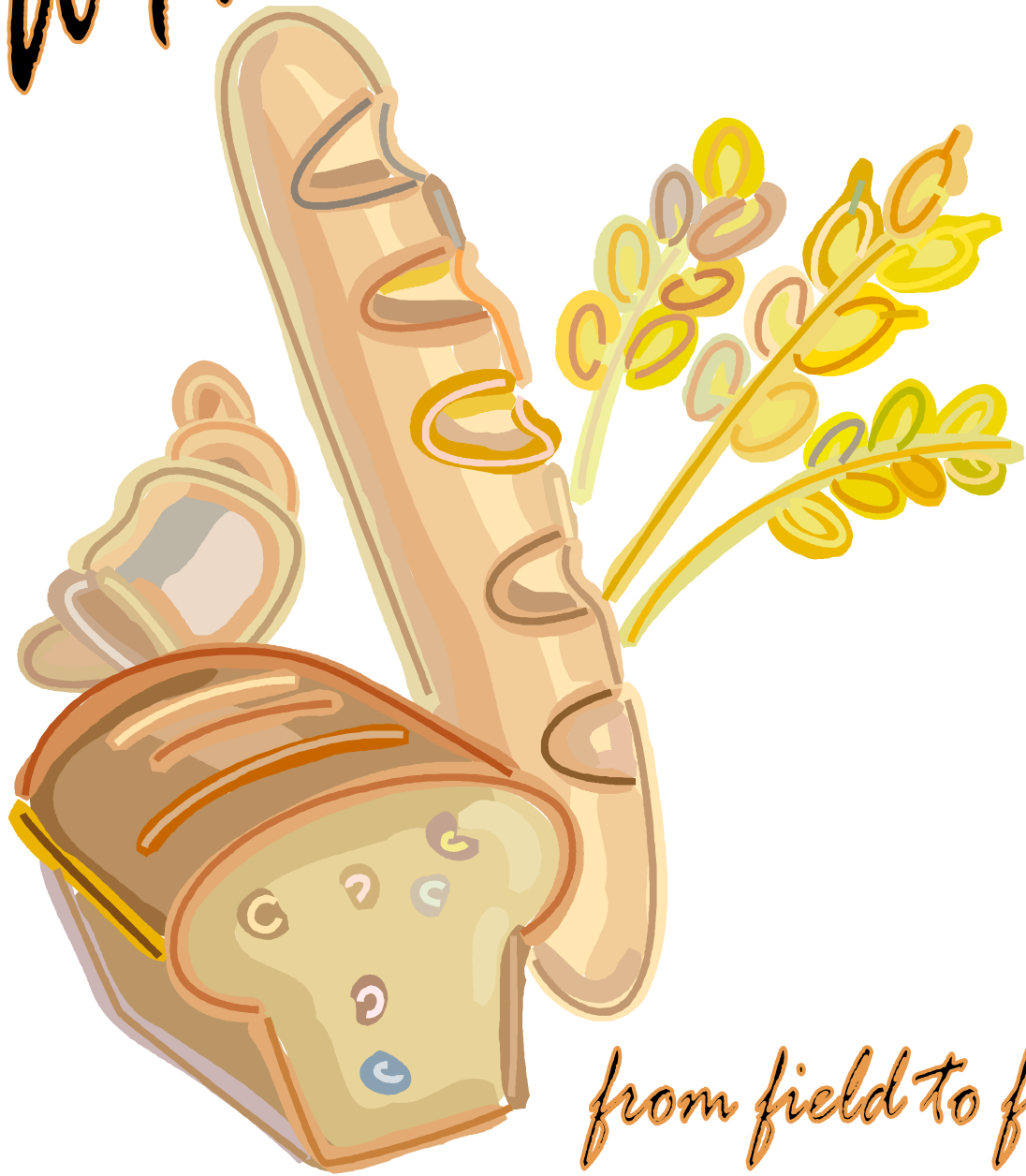


# WHEAT



*from field to flour*

a resource on the production of wheat and the science of creating flour

# TABLE OF CONTENTS

Introduction.....	1
<b>Part 1 – WHEAT PRODUCTION.....</b>	<b>3</b>
Parts of the Wheat Plant.....	4
Wheat Growth Stages (Feeke’s System).....	5
Classes of Wheat.....	8
Wheat Products.....	10
Raising Wheat.....	11
Planting and Harvest Dates.....	14
The Market.....	15
United States Grade and Grade Requirements.....	16
<b>Part 2 – THE SCIENCE OF WHEAT AND FLOUR.....</b>	<b>17</b>
Why Eat Wheat.....	18
A Kernel of Wheat.....	20
Wheat Flour.....	21
Milling.....	22
Milling Today.....	24
How Wheat is Milled (diagram).....	28
<b>Wheat and Flour Testing Methods.....</b>	<b>31</b>
Moisture Content.....	32
Protein Content.....	33
Ash Content.....	34
Flour Color Analysis.....	35
<b>REFERENCES.....</b>	<b>36</b>

# Wheat: From Field to Flour

Published by: Nebraska Wheat Board  
P.O. Box 94912  
Lincoln, NE 68509

Designed by: Cody Dvorak

Printed by: Nebraska State Administrative Services-Materiel Division; Printing Services  
Lincoln, NE

Funding for this publication is supported by the Nebraska Wheat Board. Much of this information was gathered from a variety of offices supported by the Nebraska Wheat Board. Information in this text is designed as a supplement to agricultural education and is subject to change without notification.

Use of this publication is at the discretion of each individual. Reproduction of this publication by photocopy, email, fax, and other electronic forms of reproduction is permissible.

Thank you to our constituents for providing the original sources of information used in producing this publication.

This information was compiled by Cody Dvorak, 2008-2009 Nebraska Wheat Board intern.

May 8, 2009

# INTRODUCTION

Wheat flour is one of the most nutritious plant foods available, offering an array of minerals and critical nutrients. Per capita consumption of wheat in the United States exceeds that of any other single food staple; however, not all wheat is equal. There are many types, varieties and different properties to the different grains. Wheat is classified into six classes (classes are described on page 6) and over 30,000 varieties. Wheat is not only used to make food but it is also a component of glue, paper and pet food, among other products. Wheat is one of the most important foods to the United States in terms of health as well as the economy. It is a staple in most Americans' diets and has properties that can't be replaced by other cereal grains.

Over 17,000 years ago, humans gathered and ate plant seeds. At this time they discovered the berry of the wheat plant was edible. Around 8,000 years ago, Swiss lake dwellers ground and mixed early wheat with water, then baked it to make unleavened cakes or bread. The Egyptians were the first to discover leavened bread over 5,000 years ago. Today, we still eat the wheat berry but unlike 17,000 years ago, we eat a refined product of wheat rather than chewing on raw kernels.

The top five producing countries of the world's total wheat supply in 2005-06 were:

1. China – 15.4 percent (of world supply)
2. India – 11.5 percent
3. United States – 9.1 percent
4. Russia – 7.3 percent
5. France – 5.9 percent

In 2008, the United States produced 2.5 billion bushels of wheat. Harvested area of land totaled 55.7 million acres resulting in an average yield of 44.9 bushels/acre. The top wheat producing states (in order of production) in 2008 were Kansas, North Dakota, South Dakota, Oklahoma and Montana.

In 2008, Nebraska ranked 12th in total wheat production and ninth in total winter wheat production. All of Nebraska wheat is winter wheat of which 98 percent is Hard Red Winter (HRW) and 2 percent is Hard White (HW). Production in 2008 totaled 73.5 million bushels with an average yield of 44 bushels/acre.







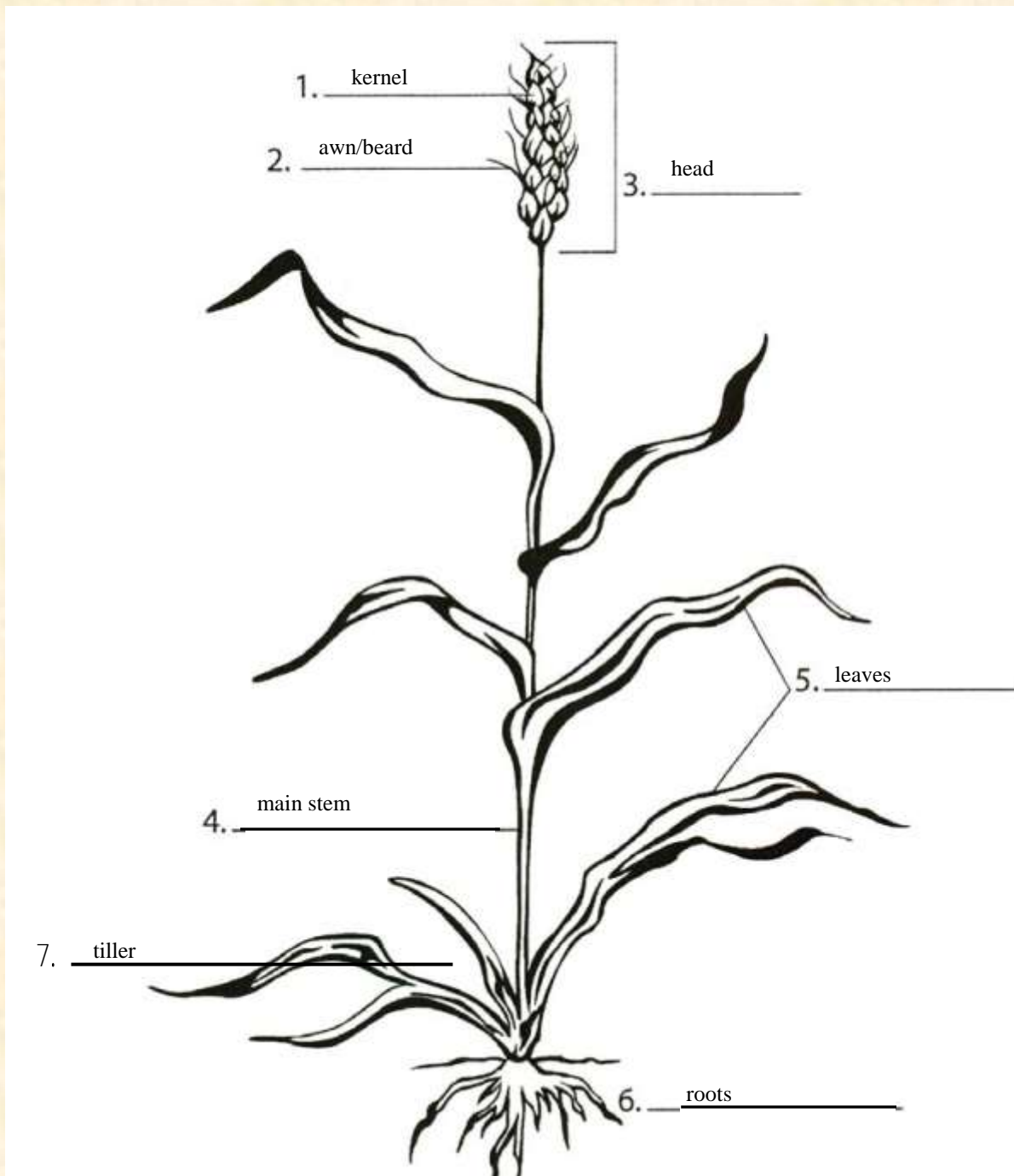
# WHEAT



# PRODUCTION



# PARTS OF THE WHEAT PLANT

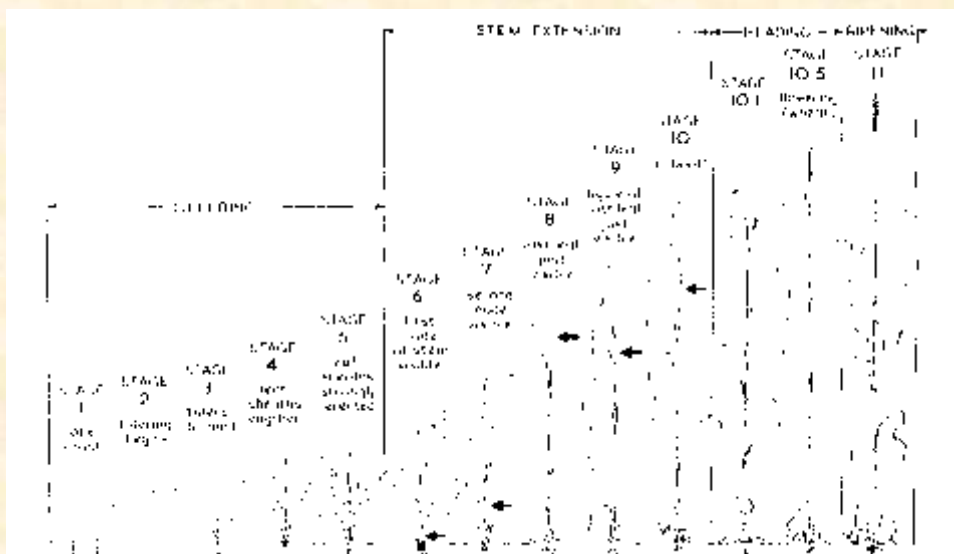
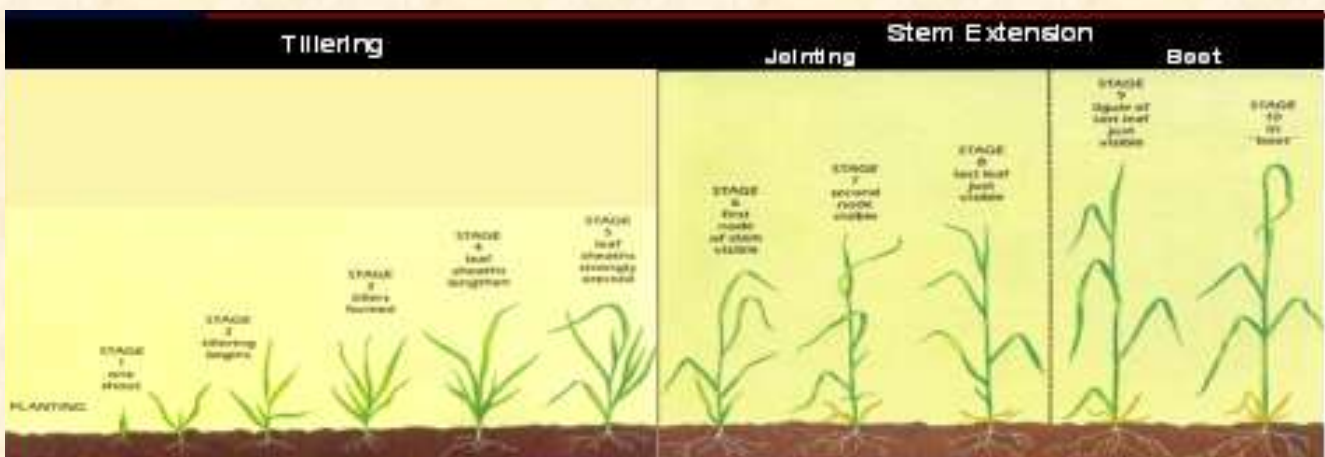


# WHEAT GROWTH STAGES (FEEKE'S SYSTEM)

Being able to determine the growth stage of wheat is important in deciding cultural practices during the duration of the plant. Fertilizers, pesticides, and other chemicals should or should not be applied at certain points during the plant's life. By understanding what stage the plant is in, producers can determine the correct cultural practices.

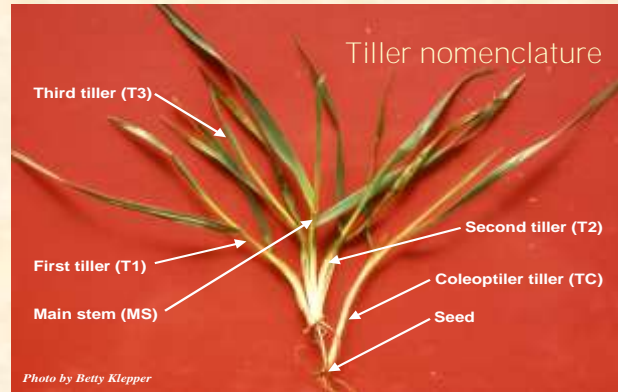
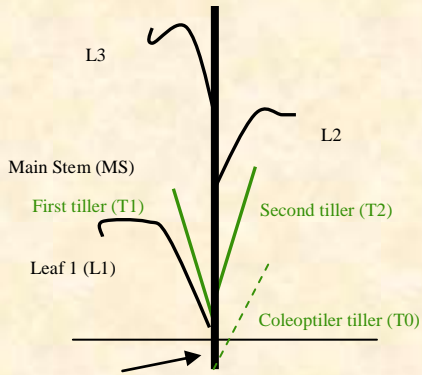
The vegetative growth (before spike emergence) of wheat can be divided into three main stages: tillering, jointing and booting. Following that are the reproductive growth stages of heading, and kernel ripening. Once the reproductive stages begin, the plant is still growing vegetatively in height and dry matter accumulation in parts of the plant other than just the grain. This is referred to as indeterminate growth (as opposed to corn which exhibits determinate growth, meaning it stops vegetative growth once reproductive stages begin).

There are many methods used today to determine the stage of wheat but the most commonly used system is the Feeke's System shown below.



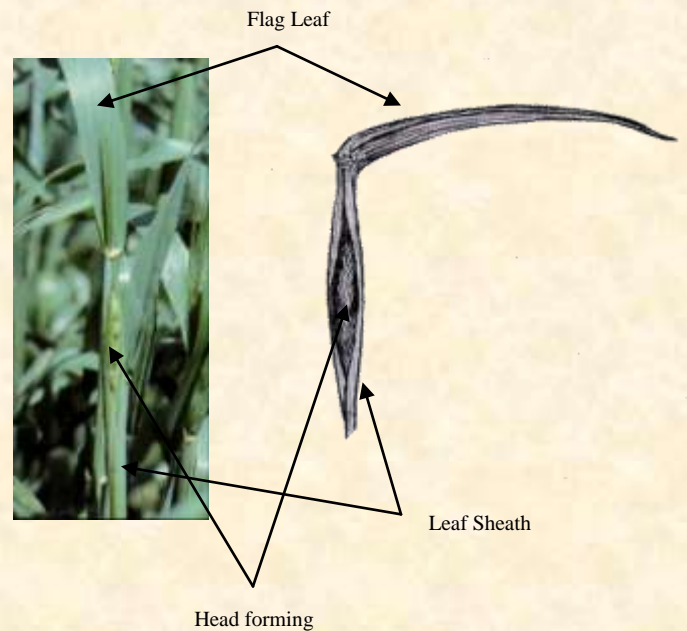
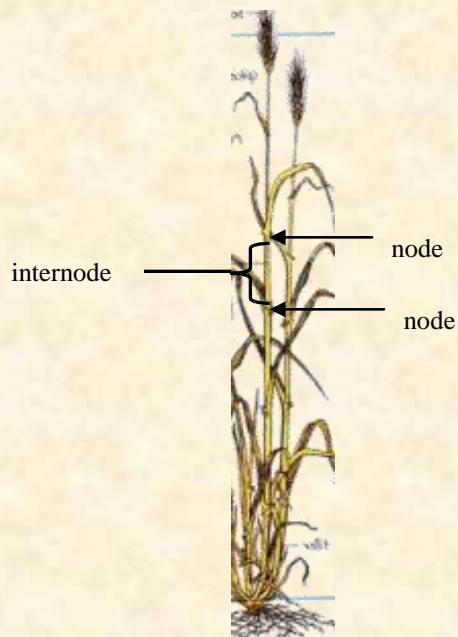


Vegetative growth in the tillering stage is determined by tillers present as shown here. Many tillers are formed, and formation may be interrupted or completed prior to the onset of winter. (2.0)



After the plant finishes forming tillers it begins elongation of its internodes. This stage will not occur before vernalization (6.0)

The boot stage initiates when the head begins to form inside the sheath of the flag leaf. (10.0)



The final stage of vegetative growth is spike emergence. This occurs when the head is fully emerged from the stem. After this takes place, the plant starts reproductive growth. Wheat is self-pollinating.

(10.5)



The flowering stage begins once the anthers emerge.

(10.5.1)



Immediately following emergence of all anthers, the ripening stage starts. The ovaries are pollinated and the seed begins to mature.

(11.0)



Wheat is ready to harvest when pressure from one's thumb applied to the kernel does not create a dent. This means that the grain is physiologically mature and has lost enough moisture to be harvested and stored.



The ripening stage is divided into four levels of maturity:

- 11.1 Milk
- 11.2 Dough
- 11.3 Kernel Hard
- 11.4 Harvest Ready



# CLASSES OF WHEAT

There are six market classes of wheat grown in the United States. Within the six classes, there are over 30,000 varieties. The six classes are categorized according to hardness, color and growing season.

Each class is produced in a specific area of the United States due to its specifications for climate, soil type and topography. Each class also has its own unique milling characteristics, making each class unique for specific uses in baking or other food uses.

The major wheat classes in Nebraska are Hard Red Winter and Hard White. Hard White Wheat accounts for about 1.9 percent of the total production in Nebraska and continues to rise.



HARD RED WINTER

HRW wheat has good characteristics for milling and baking. The majority of HRW wheat is produced in the Great Plains states between the Mississippi River and Rocky Mountains as well as significant amounts in California. HRW wheat has a significant amount of protein and is typically used in breads, rolls, all purpose flour, and some sweet goods.



HARD RED SPRING

HRS wheat is another important bread wheat. It maintains the highest protein content of all the classes, usually 13-14%. It is primarily grown in the north central United States and has good milling and baking characteristics. Primary producers are North Dakota, South Dakota, Minnesota, and Montana.



SOFT RED WINTER

SRW wheat is grown primarily in the eastern half of the United States. It is a high yielding wheat but relatively low protein, usually around 10%. Uses for SRW wheat include cakes, pastries, flat breads, crackers, and snack foods.



DURUM

**Durum is the hardest of all U.S wheat. Because of its hardness it is ground into semolina flour, the base product for pastas such as spaghetti, and macaroni.** Spring seeded Durum is grown in the north central states of North Dakota, South Dakota, and Montana (70-80% of annual production coming from North Dakota). Spring seeded varieties are also grown in southern California and Arizona.



HARD WHITE

HW wheat is the newest class of wheat to be grown in the United States. It is used in oriental noodles, yeast breads, flat breads, hard rolls, and tortillas. It has similar milling and baking qualities of the red wheats, but with a sweeter, more mild flavor.

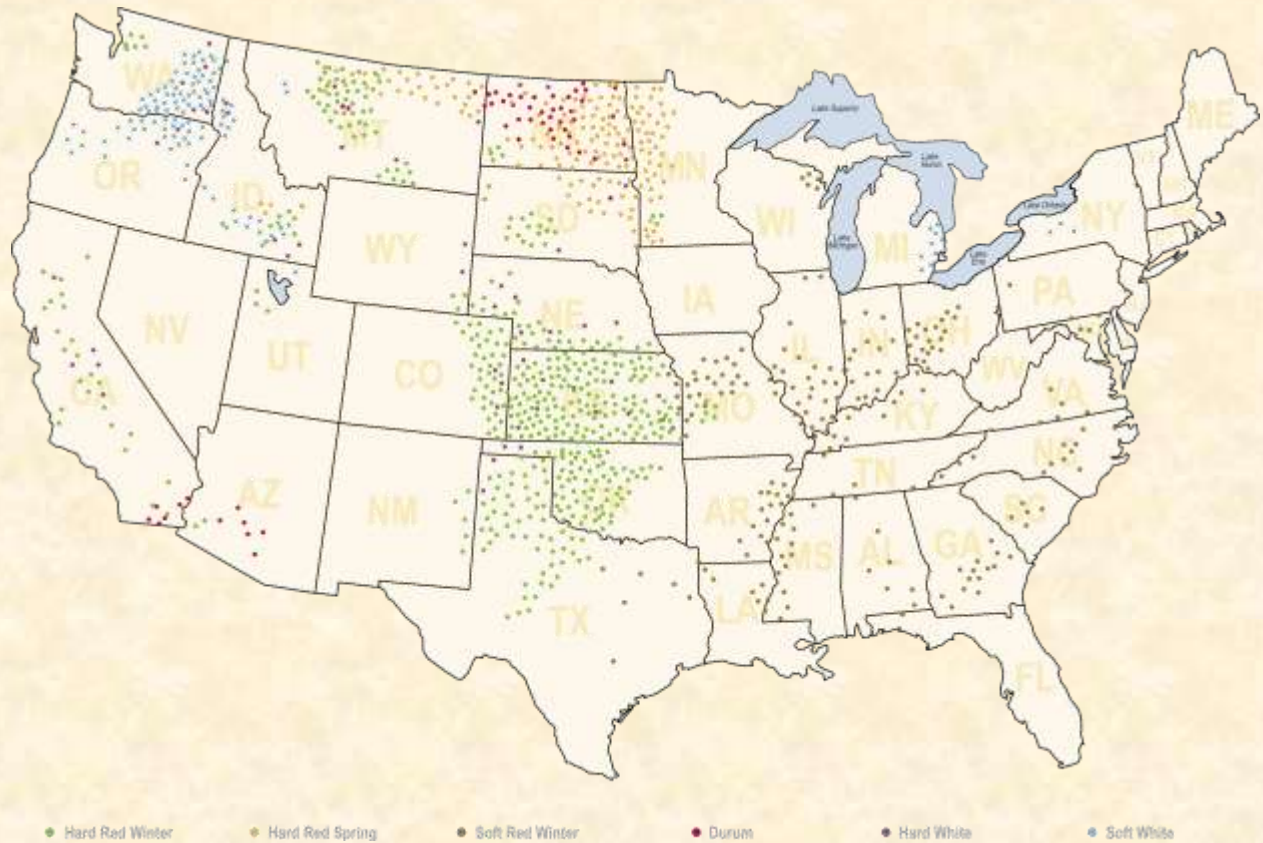


SOFT WHITE

SW wheat is a preferred wheat for flat breads, cakes, pastries, crackers, and noodles. It is grown primarily in the Pacific Northwest, specifically in states of Washington, Oregon, and Idaho although there are still acres in New York, and Michigan. SW wheat is a relatively low protein wheat, approximately 10% although it is a high yielding wheat.







As the map shows, not every class of wheat is grown everywhere. Each class has its own specifications and requirements to produce optimally. Some wheat requires a certain amount of moisture. Others require a specific temperature range. Some wheat requires a specific type of soil to grow in. And certain classes have specific growing seasons very different from other classes.

Geography and climate indicate what type of wheat can be grown in a specific area. Even though wheat is a versatile grain with six classes suited to different growing conditions, there are parts of the country not well suited for growth. These areas may not have temperatures and/or rainfall required for proper growth of the crop or they may have soils better suited to other types of production agriculture.





# WHEAT PRODUCTS

cosmetics



paper



pet food



body/laundry soap & shampoo



Carry-out containers



insulation



trash bags



particle board



# RAISING WHEAT

The six classes of wheat and their thousands of varieties make wheat suitable to various climates in vast areas of the world. Each class and variety has its own unique specifications for temperatures, elevation and water requirements, but there is also much diversity within the classes. More of the world's surface is covered by wheat than any other food staple. Wheat can be grown all the way from the Arctic Circle to the equator, at sea level or on rolling, high-altitude slopes. In fact, somewhere in the world, wheat is being harvested every month of the year.

**Spring wheat** – planted just before or during April. Spring wheat grows throughout the spring and summer months and is usually harvested around the beginning of August.

**Winter wheat** – planted just before September in the Northern United States and continues through October in the Southern regions. After planting, the seed will grow into a plant and continue to go through the tillering stage, but will not joint before reaching a cool point known as **vernalization**.

*Vernalization* is a necessary process all winter wheat varieties go through. The wheat must submit to a certain amount of cool temperatures before it joints and flowers. The optimum temperature for vernalization of winter wheat is between 40°F and 50°F; not around freezing temperatures, contrary to popular belief. Winter wheat can be submitted to temperatures so cold that the plant undergoes a process called “winterkill.” For this reason, a layer of snow is often desired on the topsoil to act as an insulation between the soil and the air. Under normal field conditions, eight to 12 weeks of growth is usually required before vernalization temperatures set in for the full development of winter hardiness.

Wheat did not originally have a winter adaption process. Through evolution, wheat has developed adaptive mechanisms to cool temperatures. After winter hardening, wheat can reverse its dormancy when the weather becomes warm again. Cold acclimation of winter wheat begins once fall crown temperatures drop below 48°F. Likewise, in the spring, when crown temperatures rise above 48°F, winter wheat dehardens.

The crown temperature is different from the air temperature because soil holds a certain amount of cold/warmth after air temperatures considerably change. The crown of the wheat plant remains below the soil surface and takes on the temperature of the soil rather than the temperature of the air. Therefore, several weeks of cold/warm air temperatures are required to cool/warm the crown of the wheat plant to a temperature similar to the air.

**Durum** – Durum is a spring-seeded wheat, harvested in late July or early August. It is milled into high-protein semolina flour used to make high-quality pasta products such as macaroni and spaghetti.



## TILLING AND PLANTING

The method of planting wheat has greatly evolved over the years. Humanity went from seeding crops by hand to using horses or oxen to make the job easier. Through the years, humans have developed more and more sophisticated machinery to pull the plows and planters required to seed crops, including wheat. Now, tractors can be guided by GPS or Global Positioning System that literally steers the tractor by utilizing a complex set of satellites orbiting the earth in space.

Wheat like most other crops can be planted in either tilled soil or in minimum/no-till soil. Tilled soil means the previous crop in that field is plowed or disked under to create looser, more arid soil.

Minimum and no-till practices save on fuel and help minimize soil erosion. Soil conservation is very important so a farmer can continue to use the same piece of land, year after year and generation after generation. If too much topsoil is lost due to erosion, it will become infertile and be very difficult to revert into good farming ground again. On the other hand, planting wheat into untilled soil may result in increased insect and plant disease problems left from the previous crop.



Wheat planted into old crop residue



Tractor pulling a disk through a field of wheat

Another practice producers may choose to utilize is referred to leaving a field **fallow** or unplanted for a year. Fallow fields are usually in a rotation with other fields, creating an every-other-year harvest on that particular field. Leaving a field unplanted for one year stores moisture in dry regions as long as the farmer makes sure the field remains weedless.

Wheat may be utilized as pasture in the Great Plains of Texas, Oklahoma, and southern Kansas. Winter wheat classes can be grazed either before winter, during early winter or in early spring. Wheat can be grazed between the 6 inch height and jointing stage, after which grazing should be ceased in order to attain a grain crop. Grazing at this point will cause significant depletion of the grain harvest yield. If there is no intention of harvesting the wheat field for grain, it may be grazed for a longer period of time. Each individual farmer determines whether the reduced grain yield/no yield is profitable for their operation. This decision can fluctuate from year to year, depending upon the price of wheat versus beef cattle prices.



Air seeder



Grain Drill





## HARVEST

Wheat begins to ripen in the southern United States in late May, progressing northward throughout the summer until spring wheat is harvested near the Canadian border after August first.

Just as the procedures to plant wheat have evolved over the years, so have the harvesting methods. Over four thousand years ago a sickle and scythe were used to cut the grain. This process was very time consuming and labor intensive.



### Reaping

The reaper was developed in 1830 by a Virginia farmer, Cyrus McCormick. The machine was designed to cut the wheat at a specific height then men gathered the bundles into sheaves. Eventually the reaper was designed to bundle the sheaves itself. After the sheaves were bundled they were gathered by the reaper and the grain was **flailed** (beat) off the **chaff** (stems).

### Threshing

Threshing, or thrashing in earlier days was designed to beat the grain off the wheat stems. This process was called flailing. In the days before 1770, farmers laid their cut wheat and other cereal crops on the floor of a barn to be flailed by farm animals. This worked easier than the alternative but left the “clean” grain dirty and full of rocks and animal manure which decreased the market value. The alternative to this was to beat the head of the stalk with a club like tool to loosen the grain, then throw it into the air. The lighter chaff material blew away further on the ground than the grain which was heavier. The grain was then collected and sold at the local mill.

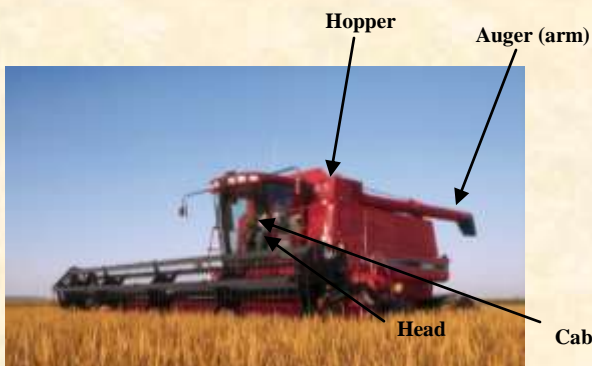
The first recorded attempt at developing a threshing machine was in 1770 by a Pennsylvania farmer, John Clayton and again in 1782 by another Pennsylvania farmer, Colonel Anderson. Both of these machines were horse powered. Throughout the years the thresher was improved and remodeled until it no longer required horses, then was combined with the reaper and winnower (cleaner) to create the first combine.

### The Combine

The first combine (stripper-harvester) was developed in 1884 by James Morrow of Victoria, Australia. The following year Hugh Victor McKay, also of Victoria, unveiled his version of a stripper-harvester. Morrow received a Victorian Government Prize for his invention but it was McKay’s version that went on to be widely distributed. Today McKay is considered the inventor of the modern combine. The development of a large scale manufacturing facility, Sunshine Harvester, in Victoria facilitated the popularity of McKay’s machine.

In the United States, the idea of the combine didn’t really catch on until shortly after World War I (1918). Today, an acre of wheat can be harvested in about thirty minutes. Thanks to the development of the combine and other helpful farm machinery, thirty-two acres of wheat can now be planted and harvested with the same amount of labor once used for one acre.

The combine cuts the wheat, threshes the grain, separates the large particles of chaff out of the grain and stores the grain in a large hopper on the combine or unloads directly to a grain cart pulled by a tractor, then onto a semi truck for transport to the local elevator or to the farmer’s private bins for storage to be sold at a later time.





# PLANTING AND HARVEST DATES

WHEAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HRW Planting												
HRW Harvest												
HRS Planting												
HRS Harvest												
SRW Planting												
SRW Harvest												
SW Planting												
SW Harvest												
HW Planting												
HW Harvest												
Durum Planting												
Durum Harvest												



# THE MARKET

After the farmer's grain is harvested he will either immediately truck the grain to a country elevator near the farm or store it in his own bins to sell at a later time. The reason for doing this is because the farmer is expecting a better price for the grain in the future. The name for the large storage facility, the elevator, is because of the moving belts used inside to move, or "elevate," the grain. The grain is purchased by the elevator's manager, often acting on behalf of a cooperative group of farmers. The wheat, whether stored at the farm or elevator, is kept in a temperature and humidity controlled environment to prevent spoilage and insect growth.

Wheat should ideally be at or below 14% moisture when harvested. If not, it is placed in special equipment called a dryer to dry. The farmer or elevator manager may either sell or hold the grain for future sale watching the market for a better price.



Grain Dryer

## GRAIN INSPECTION

The U.S. Department of Agriculture can do an official inspection of a shipment of wheat at any point in the marketing of grain. The farmer will either submit a sample or a U.S.D.A. service representative will take an official sample to record the wheat class, protein, moisture, and percentage of non-wheat material in the sample.

## GRAIN SALE

The sale of wheat may be either for export or domestic use. Approximately half of the United States wheat production is sold through both markets each year. If the wheat is sold for domestic use, it is frequently sold at a grain exchange.

A grain exchange is where U.S. grain buyers and sellers meet. The largest exchanges are located in Chicago, Kansas City, and Minneapolis. The grain exchange itself does not buy or sell. Its members represent either the individuals and companies that sell grain or the buyers, i.e., millers, brewers, feed manufacturers and exporters. They will buy on either a **cash basis**, in which the grain is delivered immediately, or on a **futures basis** for a guaranteed price at a future delivery date.

Once the grain is sold, it is transported to a terminal elevator for movement to the buyer. Trucks, rail cars, barges and ships are all part of this system.

When the grain is finally delivered, it will probably be to a mill, either in the United States or abroad.



Trading at the Kansas City Board of Trade



Country Grain Elevator



Terminal elevator loading barge



### Wheat Grades and Grade Requirements Table

Grading Factors	Grades U.S. Nos.				
	1	2	3	4	5
<b>Minimum limits:</b>					
<b>Test Weight (lbs/bu)</b>					
Hard Red Spring or White Club	58.0	57.0	55.0	53.0	50.0
All other classes and subclasses	60.0	58.0	56.0	54.0	51.0
<b>Test Weight (kg/hl)</b>					
Hard Red Spring or White Club	76.4	75.1	72.5	69.9	66.0
Durum	78.2	75.6	73.0	70.4	66.5
All other classes and subclasses	78.9	76.4	73.8	71.2	67.3
<b>Maximum percent limits:</b>					
<b>Defects</b>					
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
<b>Wheat of Other Classes 2/</b>					
Contrasting classes	1.0	2.0	3.0	10.0	10.0
Total 3/	3.0	5.0	10.0	10.0	10.0
<b>Stones</b>	0.1	0.1	0.1	0.1	0.1
<b>Maximum count limits:</b>					
<b>Other material (1000 gram sample)</b>					
Animal filth	1	1	1	1	1
Castor beans	1	1	1	1	1
Crotalaria seeds	2	2	2	2	2
Glass	0	0	0	0	0
Stones	3	3	3	3	3
Unknown foreign substance	3	3	3	3	3
Total 4/	4	4	4	4	4
<b>Insect-damaged kernels</b>					
<b>in 100 grams</b>	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, 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% 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.

**Conversion Factors**

**Wheat Equivalents:**

1 bushel =	60 pounds (27.2 kg)
36.74 bushels =	1 metric ton
37.33 bushels =	1 long ton
33.33 bushels =	1 short ton
3.67 bushels =	1 quintal
tons/ha =	0.06725 bu/acre
durum kg/hl =	lbs/bu x 1.292 + 0.630
other wheat kg/hl =	lbs/bu x 1.292 + 1.419

**Metric Equivalents:**

1 pound =	0.4536 kg
1 metric ton (MT) =	2204.6 lbs
1 short ton (2000 lbs) =	0.9072 MT, or 907.2 kg
1 long ton (2240 lbs) =	1.0160 MT, or 1016.0 kg
1 metric ton =	10 quintals
1 hectare =	2.47 acres
1 acre =	0.40 hectare
1 hundredweight =	100 pounds or 45.36 kg





# The Science



## of Wheat and Flour





# WHY EAT WHEAT?

Wheat is one of the most important foods in a balanced diet. In general people starting at the age of 14 should consume approximately 6-7 ounces of grains per day, half of which should come from whole grains. Specific amounts with regard to age and gender can be found at <http://mypyramid.gov>. One ounce of grain, in general, is equal to one slice of bread, one cup of ready-to-eat cereal, or one-half cup of cooked rice, pasta, or cooked cereal.

Wheat is primarily made up of **complex carbohydrates** which provide a source of time-released energy. The nutrition community recommends that 55-60 percent of our daily calories come from carbohydrates. Also, no more than 30 percent of our calories should come from fat, and approximately 12-15 percent of calories should be derived from protein. Clearly, calories acquired from carbohydrates such as wheat products are the healthiest and most important to incorporate in our diets.

Complex carbohydrates provide essential nutrients, are less likely to be stored as fat and more likely to be stored as muscle fuel.



So, what's in wheat that makes it so healthy? One major component in wheat which is only found in plant foods is **dietary fiber**. Dietary fiber is the carbohydrate in food which humans cannot digest. Fiber acts as a broom to sweep out the digestive tract as well as satisfying appetite longer. One slice of whole wheat bread contains 2 grams of dietary fiber; one slice of white bread contains 0.5 grams; and one ounce of wheat bran cereal contains between 8 and 9 grams of dietary fiber. The American Dietetic Association recommends eating 20-35 grams of fiber each day, but on average, Americans currently only consume about 12 grams of dietary fiber per day.



## WHEAT FOODS PROVIDE...

**Thiamin (B1)**- Needed daily for good appetite, digestion, and healthy nerves. It also helps the body make better use of fat and carbohydrates.

**Riboflavin (B2)**- This vitamin is essential for the use of protein by the body.

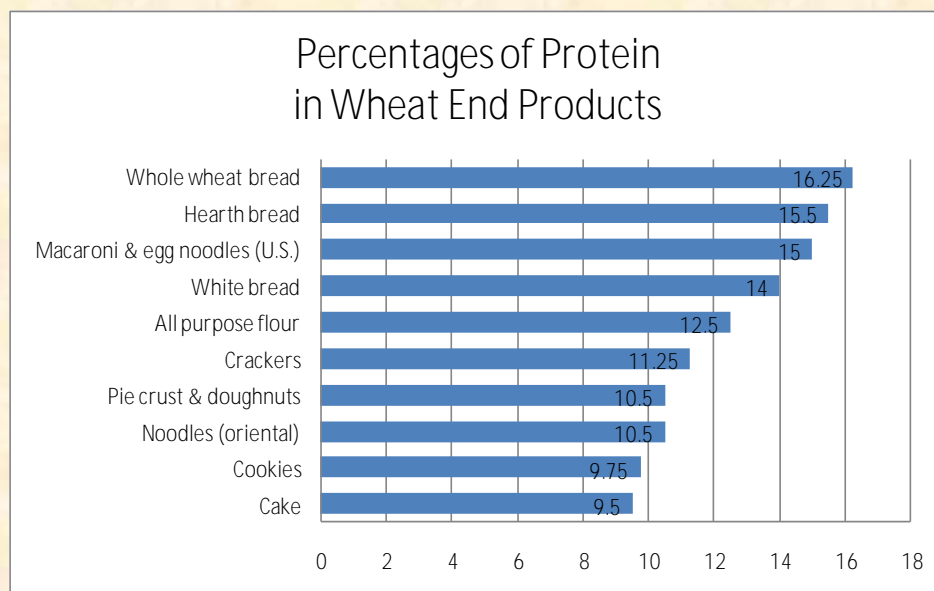
**Niacin (B3)**- This is the “anti-pellagra” vitamin. Pellagra is a nutrient deficient disease that has been virtually eliminated since the enrichment of white flour products began in the 1940’s.

**Iron**– Iron is essential for providing our bodies with energy. Iron acts in this way by carrying oxygen from the lungs to muscles and other parts of the body. A deficiency of iron causes a disease known as anemia which results in a lack of energy.

**Protein**– Wheat foods provide 2-4 grams of protein per one ounce serving. Six to seven ounces of protein per day are required for the average teenager and adult. Protein is an important component of every cell in the body. Hair and nails are mostly made of protein. Your body uses protein to build and repair tissues. You also use protein to make enzymes, hormones, and other body chemicals. Protein is an important building block of bones, muscles, cartilage, skin, and blood.

**Insoluble fiber**– Found in wheat bran and whole grains, insoluble fiber passes through the digestive system quickly, promoting regularity and reducing the risk of colon irregularities or diverticulosis, a type of colon disease. Research suggests foods containing insoluble fiber may also help reduce the risk of colon and breast cancer when part of a low-fat diet.

**Soluble fiber**– Found in oats, beans, some fruits and vegetables and refined white flour products. Studies indicate foods containing soluble fiber may help decrease blood pressure and cholesterol levels, helping to reduce the risk of heart disease. They may also help control blood sugar levels in people with diabetes.





# a Kernel of Wheat

**The Kernel of Wheat**...sometimes called the wheat berry, the kernel is the seed from which the wheat plant grows. Each tiny seed contains three distinct parts that are separated during the milling process to produce flour.

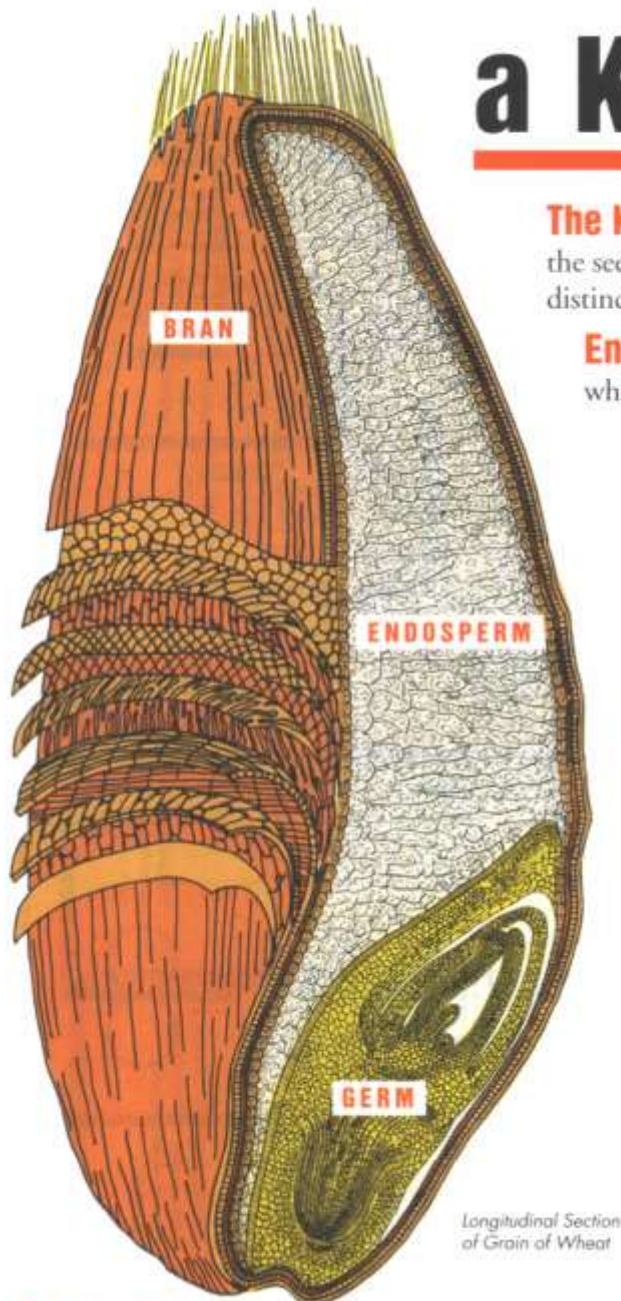
**Endosperm**...about 83 percent of the kernel weight and the source of white flour.

**Bran**...about 14 1/2 percent of the kernel weight. Bran is included in whole wheat flour and can also be bought separately.

**Germ**...about 2 1/2 percent of the kernel weight. The germ is the embryo or sprouting section of the seed, often separated from flour in milling because the fat content limits flour's shelf-life.

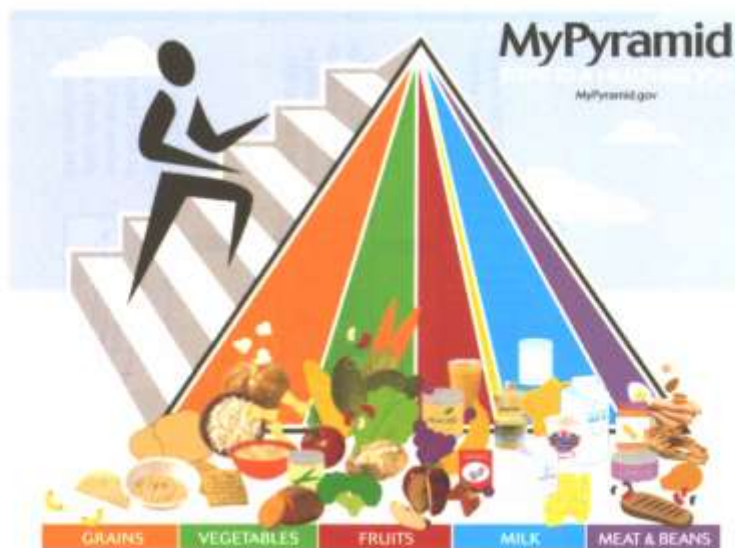
**Whole Grains**...whole grain products are made with the whole kernel of grain. The bran (outer layer) contains the largest amount of fiber (insoluble), B vitamins, trace minerals and a small amount of protein; the endosperm (middle layer) contains mostly protein and carbohydrates along with small amounts of B vitamins, iron and soluble fiber; and the germ (inner part) is a rich source of trace minerals, unsaturated fats, B vitamins, antioxidants, phytochemicals and a minimal amount of high quality protein.

**Enriched Grains**...enriched white flour is the finely ground endosperm of the kernel. Some of the nutrients that are milled out are replaced through enrichment. Slice for slice, enriched white bread as well as other enriched grain products, are a good source of iron and or B vitamins (thiamin, riboflavin, niacin and folic acid) as well as complex carbohydrates. Enriched grain products have over twice the amount of folic acid as whole wheat. Compare a slice of enriched white bread with 37mcg to a slice of whole grain bread at 17.5mcg.



Longitudinal Section of Grain of Wheat

**Grain-based Foods**...provide complex carbohydrates – the best fuel for our bodies. These foods are often low in fat and contain fiber. Grain foods provide vitamins – especially the four key B vitamins (thiamin, riboflavin, niacin and folic acid) and iron. During the milling process, white flour is produced by removing the bran and germ portions of the wheat. Most (95%) products made from white flour are enriched. Whole grain foods are made with flour that contains all three parts of the kernel. Nutrition experts recommend that at least half of our daily grains come from whole grain products. The total number needed each day depends on age, gender and activity level. MyPyramid.gov can help individuals determine the appropriate amount of foods needed.



Source: USDA/CNPP

## WHEAT FOODS COUNCIL

10841 S. Crossroads Drive, Suite 105 • Parker, CO 80138  
Telephone: 303-840-8787 • Fax: 303-840-6877  
Web Site: [www.wheatfoods.org](http://www.wheatfoods.org)  
E-mail: [wfc@wheatfoods.org](mailto:wfc@wheatfoods.org)



# WHEAT FLOUR

Wheat flour is the most important ingredient in home baking and is the framework for almost every commercially baked product and pasta. Of the grains available for the production of flour, wheat is unique. It is the only cereal grain with sufficient gluten content to make a typical loaf of bread without being mixed with other grains. For example, for one to make rye bread a certain amount of wheat flour is usually present in the end product. Breads can be made without wheat flour but they are rather rare because the bread will not rise as high and therefore will be very dense.

**All-purpose flour** is a product of the ground endosperm of hard wheat or a combination of hard and soft wheat kernels.

*Enriched all-purpose flour* has iron and B-vitamins (thiamine, niacin, and riboflavin) added in amounts equal to or exceeding that in whole wheat flour.

*Bleached all-purpose flour* is exposed to chlorine gas or benzoyl peroxide to whiten and brighten flour color. Chlorine also affects baking quality by “maturing” or oxidizing the flour, which is beneficial for cake and cookie baking. The bleaching agents react and do not leave harmful residues or destroy nutrients.

*Unbleached all-purpose flour* is bleached by oxygen in the air during an aging process and is off-white in color. Nutritionally, bleached and unbleached flour are equivalent.

**Bread flour** is ground from the endosperm of the hard red spring wheat kernel. Bread flour is usually enriched and although similar to all-purpose flour, it has greater **gluten** strength and is generally used for yeast breads.

**Self-rising flour** is an all-purpose flour with salt and leavening added. One cup of self-rising flour contains 1 1/2 teaspoons baking powder and 1/2 teaspoon salt.

**Cake flour** is milled from soft wheat and is especially suitable for cakes, cookies, crackers, and pastries. It is low in protein and low in gluten.

**Pastry flour** has comparable protein, but less starch than cake flour. It is milled from a soft, low gluten wheat and is used for pastries.

**Gluten flour** is processed from high protein wheat. It is used by bakers in combination with low protein or non-wheat flours. The increased amount of gluten improves baking quality and produces yeast breads of high protein content.

**Semolina** is the coarsely ground endosperm of durum wheat. It is high in protein and is used to create high quality pasta products such as macaroni and spaghetti.

**Durum flour** is a by-product in the production of semolina and is used for American noodles, some types of pasta and occasionally in specialty breads.

**Farina** is the coarsely ground endosperm of durum. It is used to make hot breakfast cereals, most commonly known as Cream of Wheat® or Malt-O-Meal®.

**Whole wheat flour** is flour produced from the entire berry of wheat. It includes coarsely ground bran and germ as well as endosperm in the mix. The presence of bran reduces the gluten percentage in the flour mix therefore whole wheat breads are often heavier than breads made from white flour.



Whole wheat flour is rich in B-vitamins, vitamin E and protein and contains more trace minerals and dietary fiber than white flour. Since whole wheat flour contains so many minerals, it does not have to be enriched as white flour does.

In most recipes, whole wheat flour can be mixed half and half with white flour to increase the gluten percentage.

Graham flour is another term for whole wheat flour.





# MILLING

Milling is the process used to grind wheat into flour. Flour is a value-added product derived from wheat, although rarely thought as a value added product today, because we seldom buy whole wheat to grind at home ourselves. The earliest methods of milling wheat was to find a large, sloping stone called a saddle stone and another smaller stone to hold in one's hand. The wheat berries were then ground between these two stones to create a rough form of whole wheat flour. A similar method of using a mortar and pestle was used at this time to grind wheat as well. These processes were very laborious and time consuming, and since the berries were very coarsely ground, they often wore down peoples teeth very rapidly.

Methods of milling continued to evolve until the invention of the millstone which consisted of two large horizontal, disk-shaped stones, placed one on top of the other. The top stone turned while the bottom stone remained stationary while grain was fed in between. The millstone was powered by men, horses, oxen, and finally water or wind. Romans were believed to be the first to use water power for milling flour in about 100 B.C. in Asia Minor. Windmills were developed nearly a thousand years after water mills. Their use was first recorded in Normandy and Provence, France in 1180 A.D.; Suffolk, England, in 1185 A.D.; and in Syria in 1190 A.D.

The automated mill made its first debut around 1785 by Oliver Evans. The mill included screw conveyors that moved flour and wheat horizontally and bucket elevators that lifted the grain and its milled products, called grist. Other new machines cleaned the wheat for a purer flour. By 1808 Evans granted a license to use his mill improvements to Thomas Jefferson.

By 1870, mills required fewer than three employees. Water powered two-thirds of all mills and steam powered the rest. In the middle of the 19th century with the development of harder wheat required the use of a new milling process.

In the process, the miller sets the stones wider apart to crack, rather than crush the wheat. The speed of the turning millstones was slowed at the same time. This reduced the heat of friction and ground and separated the wheat into bran and white flour by gradual reduction and repeated grinding and bolting. The flour processed was similar to modern extraction rates of 72-75 percent flour and 25-28 percent **millfeed** from a given weight of wheat.



Three key changes in milling moved it into the modern age by the later half of the 19th century.

- 1) The invention of the steam engine by James Watt (1769), and its application to American milling in the 1870's.
- 2) The replacement of millstones with two corrugated cylindrical steel rolls. Roller milling was in place in Minneapolis by 1878.
- 3) The use of the middlings purifier, constructed by Edmund la Croix in Minnesota in 1865.



The use of rollers was a cost saver because **dressing** (regrooving and repairing) millstones is expensive. Steel rollers also have to be regrooved and repaired, but it is a far different process than the work that was regularly needed on the stones.

Rollers permitted a longer, more gradual extraction without the heat produced by millstones. This resulted in a larger amount of better grade flour from a given amount of wheat. The bran was more cleanly separated from the endosperm (the flour portion of the wheat) and produced a cleaner, more uniform flour. Rollers were also superior for milling harder bread wheats.

The middling purifier added to this premium flour by blowing out the bran particles from the **middlings**, or coarse farina particles released from the wheat endosperm by the roller mill action. The farina could then be further reduced, or ground and sifted repeatedly, to extract high grade, or patent flour.

Flour extraction is important to the miller. The largest profit is in the sale of flour, not millfeed, a term used to classify all parts of the wheat that are not flour. Because an average bushel of wheat weighs about 60 pounds, the miller hopes to extract about 45 pounds of flour (75 percent) and 15 pounds of millfeed (25 percent).

Milling efficiency has increased even further with improved equipment, expanded transportation and computerization. It takes far fewer mills today to provide the flour and grain products that food processors, feed manufacturers and other industries need.

Due to the fact that weather cannot be controlled nor wheat exactly matched to an end use, the miller still takes what the farmer produces. However, today's miller fully knows the kind of wheat being milled, tests its properties, and, by scientific blending, produces a huge variety of very specific flour and grain products.



# MILLING TODAY

A closer look inside the mill shows us how flour is made and the great care and science used to make this basic ingredient for so many favorite foods. Every mill is just a little different, depending on the kind of flour needed for the end product. However, most mills follow many of the steps in roughly the same order.

## **PRODUCT CONTROL**

Wheat arrives at the mill by truck, ship, barge, or rail car. Before the wheat is even unloaded, samples are taken to ensure it passes inspection. X-rays may be used to detect any signs of insect infestation. Meanwhile, product control chemists begin their tests to classify the grain by milling and baking a small amount to determine the end-use qualities. Wheat and flour tests are described in depth in the next section.

The results from these tests determine how the wheat will be handled and stored. Millers may blend different wheats to achieve the desired end product. The wheat will then be stored at the mill in large bins. Storing wheat is an exact science. The right moisture, heat and air must be maintained or the wheat may mildew, sprout, or ferment.

## **CLEANING THE WHEAT**

The first milling step involves equipment that separates wheat from seeds and other grains; eliminates foreign materials such as metal, sticks, stones and straw; and scours each kernel of wheat. It can take as many as six steps.

### **MAGNETIC SEPARATOR**

The wheat first passes by a magnet that removes iron and steel particles.

### **SEPARATOR**

Vibrating screens remove bits of wood and straw and almost anything too big and too small to be wheat.

### **ASPIRATOR**

Air currents act as a kind of vacuum to remove dust and lighter impurities.

### **DE-STONER**

Using gravity, the machine separates the heavy material from the light to remove stones that may be the same size as the wheat kernels.

### **DISC SEPARATOR**

The wheat passes through a separator that identifies the size of the kernels even more closely. It rejects anything longer, shorter, more round, more angular or in any way a different shape.

### **SCOURER**

The scourer removes outer husks, crease dirt (dirt contained in the crease of the wheat berry) and any smaller impurities with an intense scouring action. Currents of air pull all the loosened material away.

## **CONDITIONING THE WHEAT**

### **TEMPERING**

Now the wheat is ready to be conditioned for milling. This is called tempering. Moisture is added in precise amounts to toughen the bran and mellow the inner endosperm. This makes the parts of the kernel separate more easily and cleanly.

Tempered wheat is stored in bins from 8 to 24 hours, depending on the type of wheat - soft, medium or hard. Blending of wheats may be done at this time to achieve the best flour for a specific end use.





## IMPACT SCOURER

Centrifugal force breaks apart any unsound kernels and rejects them from the mill flow. From the entoleter, the wheat flows to grinding bins, large hoppers that will measure or feed wheat to the actual milling process.

## GRINDING THE WHEAT

The wheat kernels, or berries, are now in far better condition than when they arrived at the mill and are ready to be milled into flour. Wheat kernels are measured or fed from the bins to the **rolls**, or corrugated rollers made from chilled cast iron.

This modern milling process is a gradual reduction of the wheat kernels. The goal is to produce middlings, or coarse particles of endosperm. The middlings are then graded and separated from the bran by sieves and purifiers. Each size returns to corresponding rollers and the same process is repeated until the desired flour is obtained. The rolls are paired and rotate inward against each other, moving at different speeds. Just one pass through the corrugated first break rolls begins the separation of bran, endosperm and germ.

## THE MILLERS SKILL

The miller's skill is demonstrated by the ability to adjust all of the rolls to the proper settings that will produce the maximum amount of high-quality flour. Grinding too hard or close results in ban powder in the flour. Grinding too open allows good endosperm to be lost in the mill's feed streams. The miller must select the exact milling surface, or corrugation, on the break rolls, as well as the relation and the speed of the rollers to each other to match the type of wheat and its condition. Each break roll must be set to get as much pure endosperm as possible to the middlings rolls. The middlings rolls are set to produce as much flour as possible.

From the rolls, the grist (ground wheat) is sent way upstairs to drop through sifters. The grist is moved via pneumatic systems that mix air with the particles so they flow, almost like water, through tubes. This is a great advance in health and safety from earlier methods of moving the grist with buckets.

## SIFTERS

The broken particles of wheat are introduced into huge, rotating, box-like sifters where they are shaken through a series of bolting cloths or screens to separate the larger from the smaller particles. Inside the sifter, there may be as many as 27 frames, each covered with either a nylon or stainless steel screen, with square openings that get smaller and smaller the farther down they go.

Up to six different sizes of particles may come from a single sifter, including some flour with each sifting. Larger particles are shaken off from the top, or **scalped**, leaving the finer flour to sift to the bottom. The scalped fractions are sent to other roll passages and particles of endosperm are graded by size and carried to separate purifiers.

## PURIFIERS

In a purifier, a controlled flow of air lifts off bran particles while at the same time a bolting cloth separates and grades coarser fractions by size and quality.

Four or five additional break rolls, each with successively finer corrugations and each followed by a sifter, are usually used to rework the coarse stocks from the sifters and reduce the wheat particles to granular middlings that are as free from bran as possible. Germ particles will be flattened by later passage through the smooth reduction rolls and can be easily separated. The reduction rolls reduce the purified, granular middlings, or farina, to flour.

The process is repeated over and over again, sifters to purifiers to reducing rolls, until the maximum amount of flour is separated, consisting of close to 75 percent of the wheat. The remaining percentage of the wheat kernel or berry is classified as millfeed—shorts, bran and germ.



Bakers buy a wide variety of flour types, based on the products they produce. The flour the consumer buys at the grocery store, called **family flour** by the milling industry, is usually a long-patent all-purpose or bread flour. Occasionally short patent flour is available in retail stores.

**Reconstituting**, or blending back together, all parts of the wheat in the proper proportions yields whole wheat flour. This process produces a higher quality whole wheat flour than is achieved by grinding the whole wheat berry. Reconstitution assures that the wheat germ oil is not spread throughout the flour so it does not go rancid so readily.

#### BLEACHING FLOUR

Toward the end of the line in the millstream, if the flour is to be bleached, the finished flour flows through a device which releases a bleaching-maturing agent in measured amounts.

It has been known for centuries that freshly milled flour makes a lesser quality baked product. In the old days, flour was stored for a few months to mature, or naturally oxidize. This whitened the flour and improved its baking characteristics. The modern bleaching process simply duplicates this natural oxidation process, but does so more quickly.

In the bleaching process, flour is exposed to chlorine gas or benzoyl peroxide to whiten and brighten flour color. Chlorine also affects baking quality by **maturing** or **oxidizing** the flour, which is beneficial for cake and cookie baking. The bleaching agents react and do not leave harmful residues or destroy nutrients.

#### ENRICHMENT

What is an important source of iron in the diet, especially for those who eat few eggs or little red meat? Why is beriberi no longer a public health concern?

The enrichment of flour with three B vitamins (thiamin, niacin and riboflavin) and iron, begun in the 1930s, is the answer to both questions.

The flour stream passes through a device that measures out specified quantities of enrichment. If the flour is self-rising, a leavening agent, salt and calcium are also added in exact amounts.

Before the flour leaves the mill, additional lab tests are run to ensure that the customers get what they ordered. Finally, the flour millstream flows through pneumatic tubes to the packing room or into hoppers for bulk storage. Family flour for retail sale may be packed in 5, 10, or 25 pound bags. Bakery flour may be packed in 50-100 pound bags or sent directly to bulk trucks or rail cars.

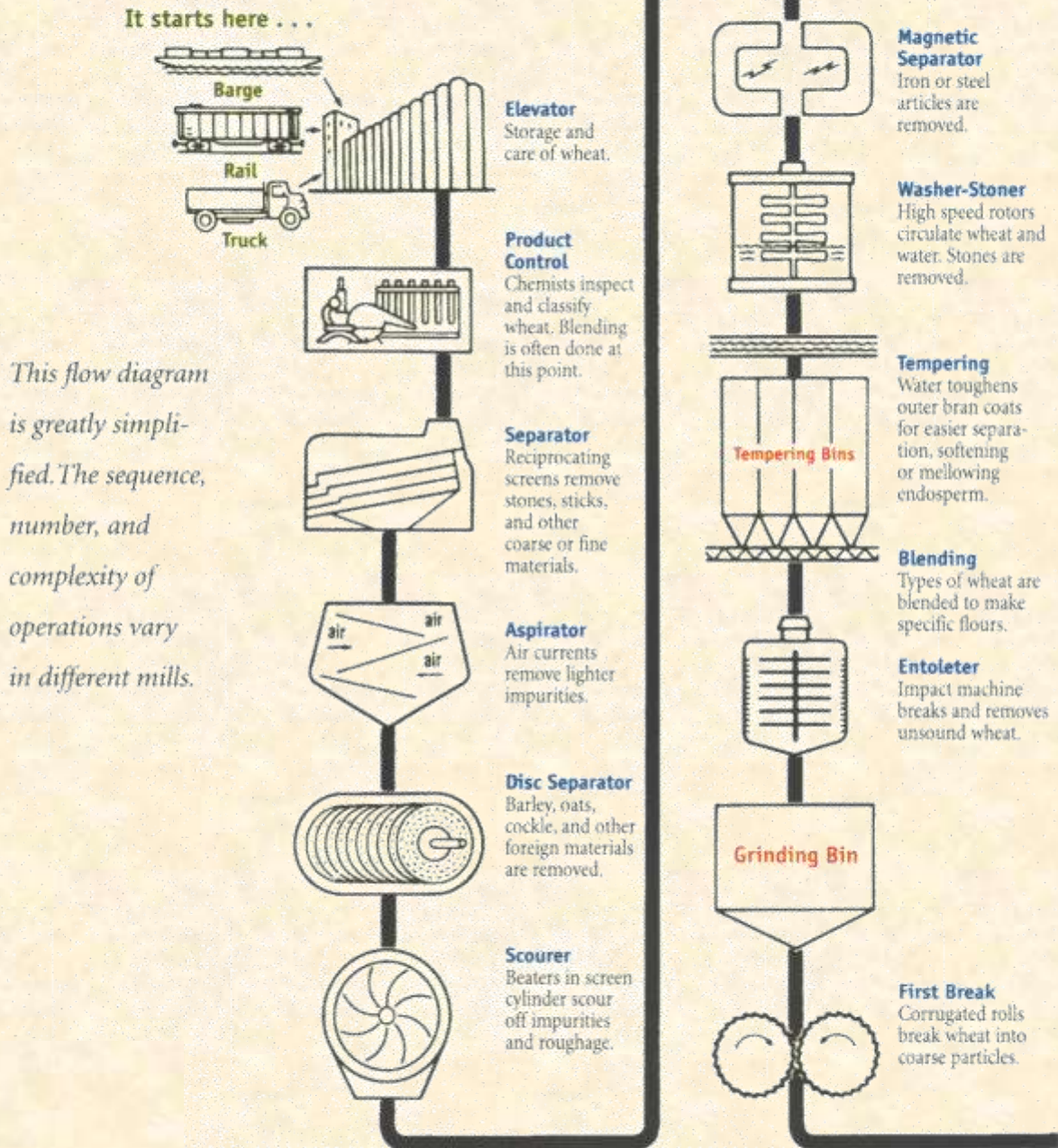








# How Wheat is Milled



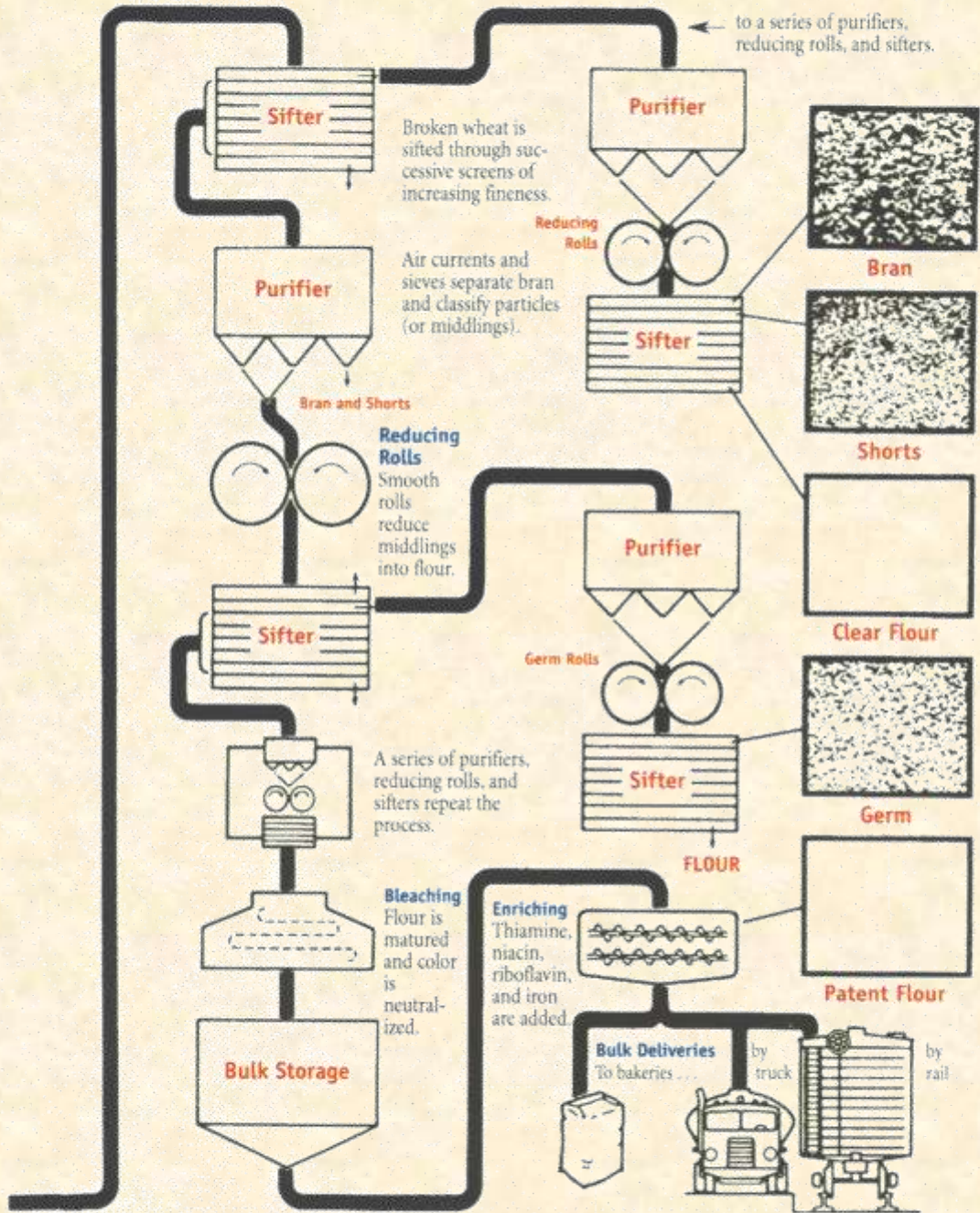
*This flow diagram is greatly simplified. The sequence, number, and complexity of operations vary in different mills.*

Courtesy of Wheat Foods Council, 10841 S. Crossroads Drive, Suite 105, Parker, Colorado 80138





SIMPLIFIED COMMERCIAL MILLING PROCESS DIAGRAM



Milling Process





**Bran**



**Whole Wheat Flour**

**All Purpose Flour**





# Wheat and Flour



# Testing Methods



# Moisture Content

- ◆ Low temperature heating
- ◆ Measures moisture content



*Flora Engelmann, Laboratory Technician*

## Method

1. 2-3 grams of flour is weighed and placed in a moisture dish.
2. Sample is heated to 266°F in an air oven for one hour.
3. Sample is cooled to room temperature and the residue is weighed.

## Results

- Moisture content is determined by comparing the weight of the sample before and after heating.
- The amount of weight loss is the moisture content.
- This amount is expressed as a percentage. An example of a common HRW wheat moisture is 11.4%.

## Why is this important?

The information in this test is often used as a basis for other tests. Wheat/flour is often required to have a unified moisture content in subsequent tests.

Wheat or flour with a high moisture content (over 14.5%) attracts mold, bacteria, and insects, all of which cause deterioration during storage.



# Protein Content

- ◆ High Temperature combustion
- ◆ Measures protein content



*Tina Tran, Laboratory Technologist*

Combustion Nitrogen Analysis (CNA) is one of several methods used to determine protein content in flour or wheat.

## Method

- 1) A sample of flour or ground wheat (0.15-0.20 grams) is weighed and placed into a CAN protein analyzer.
- 2) This process is fully automated and begins by dropping the sample into a hot oven where it is burned at 1,746°F.
- 1) The amount of nitrogen gas released during burning is measured and a formula is applied to convert this measurement to protein content in the sample.

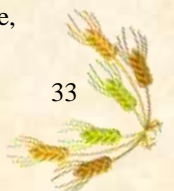
## Results

- Since protein is the major wheat compound that contains nitrogen, the protein content can be determined by measuring the amount of nitrogen released during burning.
- Protein content results are expressed as a percentage of the total sample weight; for example, 10% protein content on 12% moisture basis for wheat or 8.5% on 14% moisture basis for flour.

## Why is this important?

Protein is related to many processing properties, such as water absorption and gluten strength. Protein content can also be related to finished product attributes, such as texture and appearance. Low protein content is desired for crisp or tender products, such as snacks or cakes. High protein content is desired for products with chewy texture, such as pan bread and hearth bread.

Protein content also reveals water absorption and dough development time. Higher protein content usually requires more water and longer mixing time to achieve optimum dough consistency.





# Ash Content

- ◆ High temperature incineration
- ◆ Measures mineral (ash) content



*Kevin Marquardt, Laboratory Technologist*

## Method

- 1) A sample of flour or ground wheat (3-5) grams is weighed and placed in an ash cup.
- 2) The sample is heated to 1,085°F in an ash oven until its weight is stable. (Usually overnight).
- 3) The residue is cooled to room temperature and then weighed.

## Results

- The high temperature of the oven drives out the moisture and burns away all organic materials (starch, protein, and oil), leaving only the ash. The residue (ash) is composed of the non-combustible, inorganic minerals that are concentrated in the bran layer.
- Ash content results for wheat or flour ash are expressed as a percentage of the initial sample weight; for example, wheat ash of 1.58% or flour ash of 0.52%. Wheat or flour ash is usually expressed on a common moisture basis of 14%.

## Why is this important?

Since ash is primarily concentrated in the bran, ash content in flour is an indication of the yield that can be expected during milling. Ash content also indicates milling performance by indirectly revealing the amount of bran contained in flour. White (non-whole wheat) flour is expected to have a low ash content. Ash in flour can affect color, imparting a darker color to finished products. Some specialty products requiring particularly white flour call for low ash content while other products, such as whole wheat flour, have a high ash content.



# Flour Color Analysis

- ◆ Color analysis
- ◆ Measures flour color



*Mia Biberic, Student Intern*

One method to measure flour color is the Minolta Chroma Meter Test.

## Method

- 1) A sample of flour is placed on the granular materials attachment and compacted.
- 2) The Minolta Chroma Meter is inserted into the granular materials attachment.
- 3) Measurements are taken and recorded.

## Results

- Flour color is determined by measuring the whiteness of a flour sample with the Minolta Chroma Meter.
- The rating scale is as follows...

L* value	whiteness	100 white 0 black
a* value	positive values negative values	+60 red color -60 green color
b* value	positive values negative values	+60 yellow color -60 blue color

The color values of a typical white flour, for example, are:

L\* value +92.5 whiteness  
a\* value -2.4 green color  
b\* value +6.9 yellow color

## Why is this important?

Flour color often affects the color of the finished product and is therefore one of many flour specifications required by end-users. Generally speaking, a bright white color flour is more desirable for many products.



## References

- Barge loading. Photography courtesy of Port of Milwaukee.
- Bugsy Bread. Photography courtesy of Wheat Foods Council.
- Davis, S.P. Millers National Federation. *From Wheat to Flour*. Bismarck, ND: Image Printing, Inc., 1997.
- Dhuyvetter, K.C., Fjell, D.L., Fritz, J.O., Kuhl, G.L., Langemeier, L.N., Shroyer, J.R. Cooperative Extension Service, Kansas State University, Manhattan. *Wheat Pasture In Kansas*. 1993. Retrieved February 3, 2009, from <http://www.oznet.ksu.edu/library/crpsl2/C713.PDF>
- Fowler, D.B. University of Saskatchewan. *Winter Cereal Production; Ch. 12 Winter Survival*. 2002. Retrieved January 20, 2009, from [http://www.usask.ca/agriculture/plantsci/winter\\_cereals/Winter\\_wheat/CHAPT12/cvchpt12.php](http://www.usask.ca/agriculture/plantsci/winter_cereals/Winter_wheat/CHAPT12/cvchpt12.php)
- Gibson, L., & Benson, G. Iowa State University, Department of Agronomy. *Origin, History, and Uses of Oat and Wheat*. January 2002. Retrieved January 26, 2009, from [http://www.agron.iastate.edu/courses/agron212/Readings/Oat\\_wheat\\_history.htm](http://www.agron.iastate.edu/courses/agron212/Readings/Oat_wheat_history.htm)
- Hand of Wheat. Photography courtesy of Kansas State University.
- Implement pictures. Photography courtesy of Case IH Agriculture.
- Kansas City Board of Trade. Photography courtesy of Kansas City Board of Trade.
- Montana Wheat and Barley Committee.. *Six Classes Of Wheat*. 2006. Retrieved March 30, 2009, from [http://wbc.agr.mt.gov/Consumers/classes\\_wheat.html](http://wbc.agr.mt.gov/Consumers/classes_wheat.html)
- No Till Field. Photography courtesy of Scott Osler.
- Quick Whole Wheat Pizza Crust. Photography courtesy of Wheat Foods Council.
- Roller Mill. Photography courtesy of Hebei Huangpai Machinery Co., LTD.
- Slavin, J.L. Wheat Foods Council. *The Functional Benefits of Grain Foods*. Colorado.
- Todd and Sargent Wheat Mill. Photography courtesy of Todd and Sargent.
- United States Department of Agriculture. *MyPyramid.gov*. 2009.
- United States Department of Agriculture. National Agricultural Statistics Service. *Small Grains 2008 Summary*. Washington, D.C.: September 2008.
- U.S. Wheat Associates. *Crop Quality Report 2008*. Virginia: 2008.
- Wheat anther picture (full head). Photography courtesy of Zoe Olson. 2008.
- Wheat class pictures. Photography courtesy of U.S. Wheat Associates.
- Wheat Foods Council. *About Wheat*. Colorado: 2005.
- Wheat Foods Council. *A Kernel of Wheat*. Colorado.
- Wheat Marketing Center, Inc. *Wheat and Flour Testing Methods, A Guide to Understanding Wheat and Flour Quality*. Oregon: 2004.
- Wheat– The Energy Natural. Photography courtesy of Wheat Foods Council.
- Whole Wheat Raisin Cookies. Photography courtesy of Wheat Foods Council.





Nebraska Wheat Board  
P.O. Box 94912  
Lincoln, NE 68509

PHONE: (402) 471-2358  
FAX: (402) 471-3446  
EMAIL: [wheat.board@nebraska.gov](mailto:wheat.board@nebraska.gov)  
WEBSITE: [www.nebraskawheat.com](http://www.nebraskawheat.com)