BAKER pedia

A quick reference guide from the Science of Flour class

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1. History

Wheat originated in the Tigris Euphrates Valley. It is now the most widely grown cultivated crop by humans. More wheat is produced worldwide than any other grain. The hardiness of wheat with the variety of food makes it a universal part of the human diet.

2. Wheat types and their typical uses

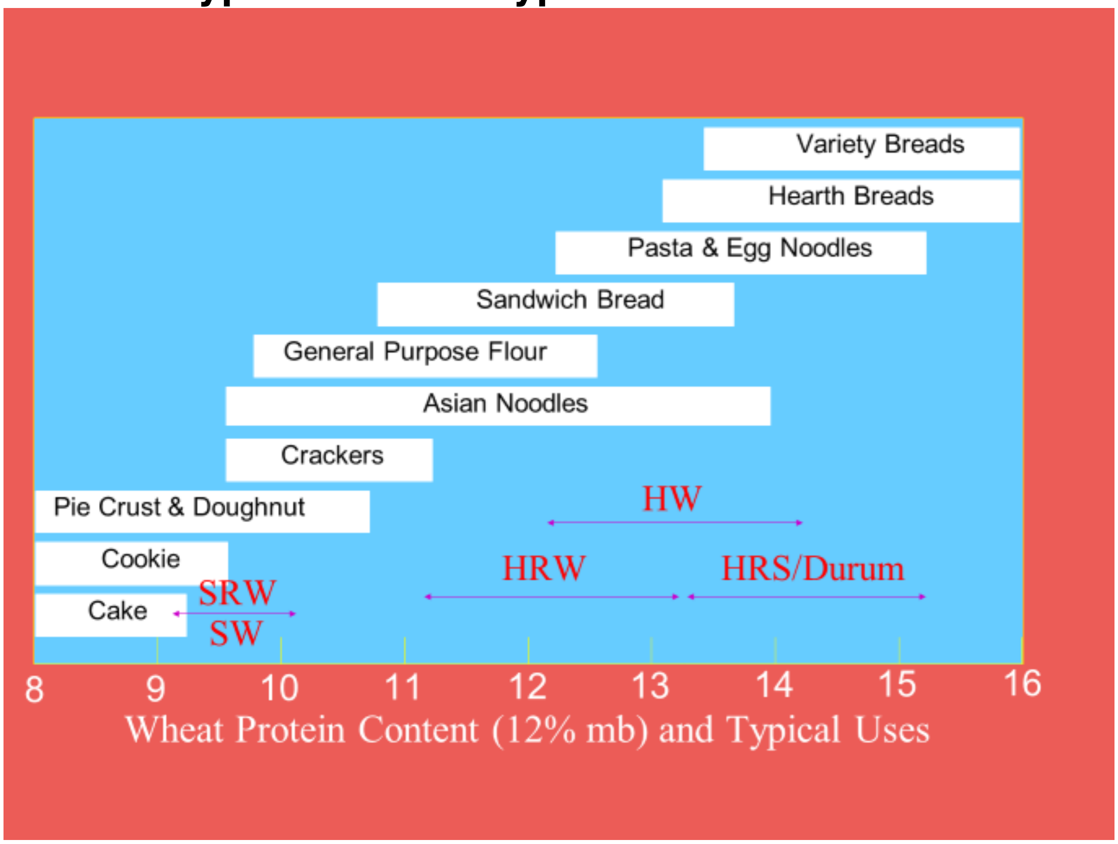

Figure 1. Wheat protein content (12% mb) and typical uses of different kinds of wheat (SRW, soft red winter; SW, soft white; HRW, hard red winter; HW, hard white; HRS, hard red spring) (Source: Wheat Marketing Center)

3. Wheat geographical locations in America

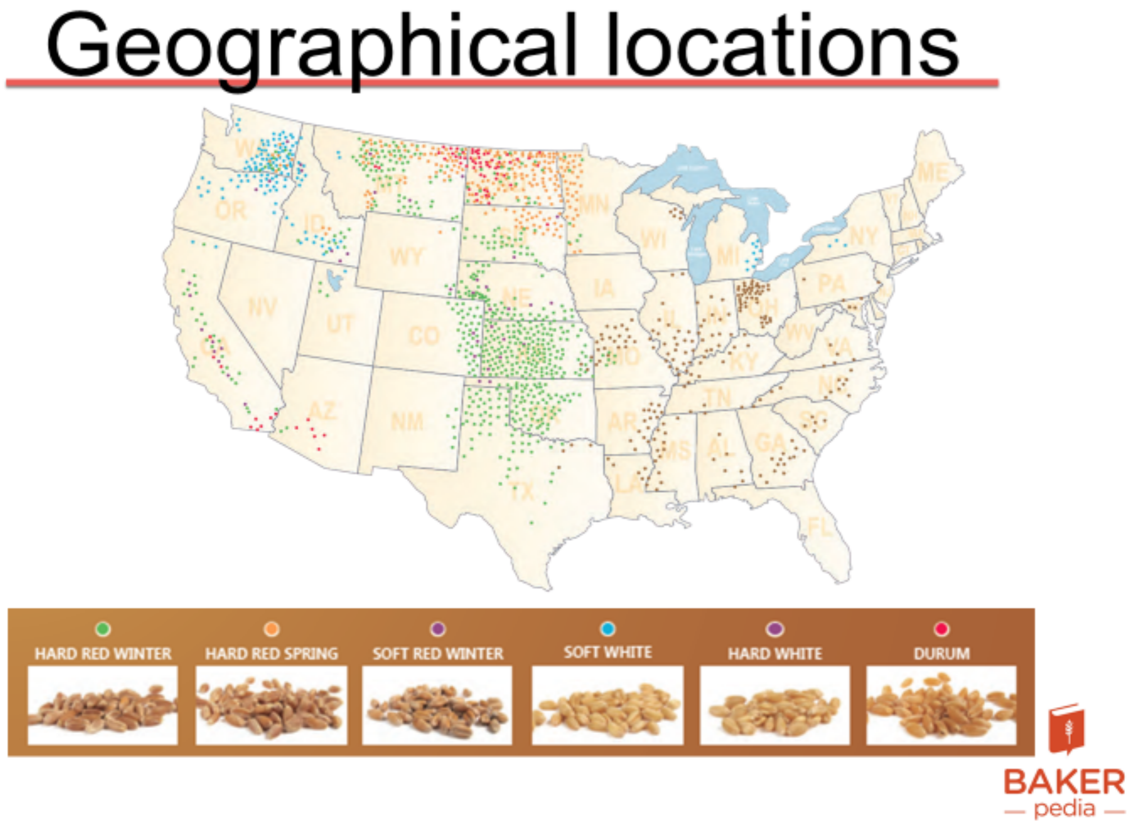

Figure 2. wheat geographical locations in America based on wheat types (Source: Wheat Marketing Center)

4. US wheat production

	2015	2014	2013	2012	2011
Hard Red Winter	22.5	20.1	20.3	27.2	21.2
Hard Red Spring	15.4	15.1	13.4	13.7	10.8
Hard White	0.6	0.6	0.6	0.6	0.7
Durum	2.2	1.5	1.6	2.3	1.4
Soft White	5.4	5.5	6.8	6.5	7.9
Soft Red Winter	9.8	12.4	15.5	11.4	12.5
Total	**55.8**	**55.1**	**58.1**	**61.3**	**54.2**

Based on USDA crop estimates of September 30, 2015.

Figure 3. US wheat production by Class (MMT) (Source: Wheat Marketing Center)

	Hard Red Winter[1]		Hard Red Spring		Northern Durum[2]		Desert Durum®		Soft White		Soft Red Winter	
	2015	5-Year Avg	2015	5-Year Avg	2015	5-Year Avg	2015	5-Year Avg	2015	5-Year Avg	2015	5-Year Avg
Test Weight (lb/bu)	59.0	60.7	61.6	61.4	60.6	60.0	62.4	62.8	59.3	60.6	56.9	58.7
(kg/hl)	77.6	79.8	81.1	80.8	78.9	78.2	81.3	81.7	78.0	79.8	75.0	77.2
Grade	2 HRW	1 HRW	1 DNS	1 NS	1 HAD	1 HAD	1 HAD	1 HAD	2 SW	1 SW	3 SRW	2 SRW
Dockage (%)	0.8	0.5	0.6	0.7	0.9	1.0	0.5	0.4	0.6	0.5	0.7	0.6
Wheat Moisture (%)	11.4	11.1	12.0	12.2	11.2	11.6	7.7	6.4	8.9	9.4	13.2	13.0
Wheat Protein (%)[3]	12.4	12.7	14.1	14.1	13.9	13.5	14.0	13.4	10.9	10.0	10.0	10.0
Wheat Ash (%)[3]	1.59	1.54	1.51	1.57	1.57	1.62	1.71	1.74	1.41	1.35	1.43	1.52
1000 Kernel Weight (g)	29.6	29.1	31.7	30.4	38.5	39.2	53.0	48.0	30.8	35.3	31.9	32.6
Wheat Falling Number (sec)	400	405	371	382	414	354	565	445	354	333	265	319
Flour/Semolina Extraction (%)	74.1	73.3	67.5	68.6	65.1	64.8	62.6	62.1	72.6	74.7	72.9	71.1
Flour/Semolina Ash (%)[3]	0.59	0.50	0.52	0.51	0.64	0.68	0.86	0.86	0.50	0.51	0.50	0.44
Wet Gluten (%)	29.2	29.5	34.3	34.7	37.0	35.1	34.6	32.5	26.0	22.6	22.6	22.4
Farinograph:												
Peak Time (min)	4.8	5.3	7.1	6.7	n/a	n/a	n/a	n/a	3.3	1.8	1.5	1.5
Stability (min)	6.9	11.9	10.8	11.0	n/a	n/a	n/a	n/a	3.1	2.9	2.6	2.8
Absorption (%)	59.6	58.5	62.1	64.0	n/a	n/a	n/a	n/a	54.2	53.5	53.4	52.6
Alveograph W (10^{-4} joules)	214	250	312	365	129	124	223	208	118	98	73	82
Loaf Volume (cc)	870	825	974	965	n/a	n/a	n/a	n/a	n/a	n/a	704	714
Production (mmt)	22.5	20.9	15.4	12.9	1.7	1.4	0.6	0.5	5.4	6.4	9.8	10.9
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Figure 4. US what production in 2015 and 5-year average (Source: Wheat Marketing Center)

5. Flour milling history

First advanced civilizations used their hands to produce flour by simple grindstones. Romans wanted to increase this supply. They ground corn in cone mills turned by slaves and animals. Vitruvius in 25 BC proposed a water mill. Windmill was introduced towards the end of the middle ages. The industrial age brought mills powered by steam engines in England. Industrial mills now produce over 320 million tons of wheat flour from milling rollers, which serves as the staple food of a third of the world's population.

6. Flour milling techniques

6.1 Stone mill

Grain is ground between two stones. The gap and rate of feed determines particle size. The hammer mill uses the same principle. Whole wheat flour is produced from the stone ground. The stone ground flour has the following advantages: (1) it has more nutrition (2) it gives people the impression of the romantic "fresh" (3) it retains full aroma in bread. The disadvantages of the stone ground flour are: (1) it has oxidative rancidity (2) the bread made from such flour is dense.

There are several stone dressing patterns, but the most popular one is called Quarter Dress (Figure 6). The top and bottom stones have the same dress pattern. The bottom stone is stationary and called bed stone. The top stone rotates and is called runner stone. The runner stone is slightly concave and the bed stone is slightly convex for helping ground flour exit the milling surface toward the outer rim. Figures 7 shows the runner and bed stones, respectively in red and black dresses.

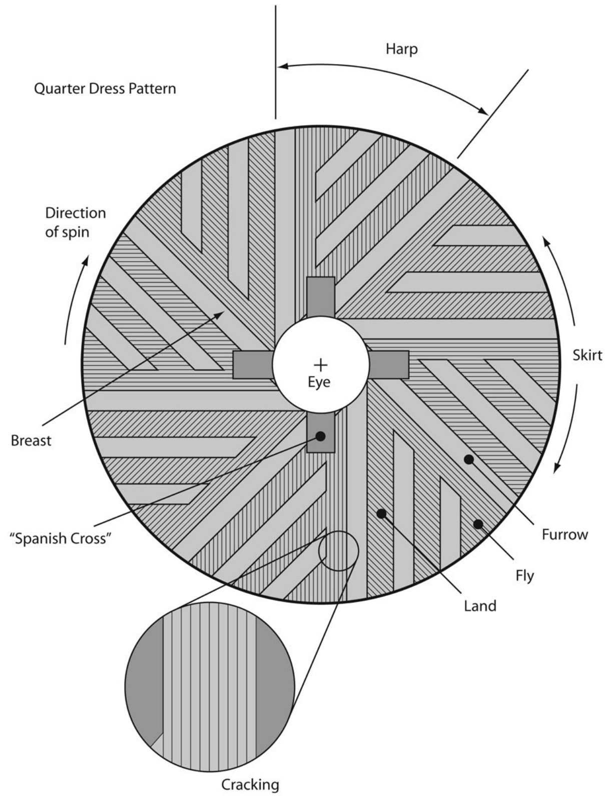


Figure 5 Quarter Dress Pattern (Source: Wheat Marketing Center)

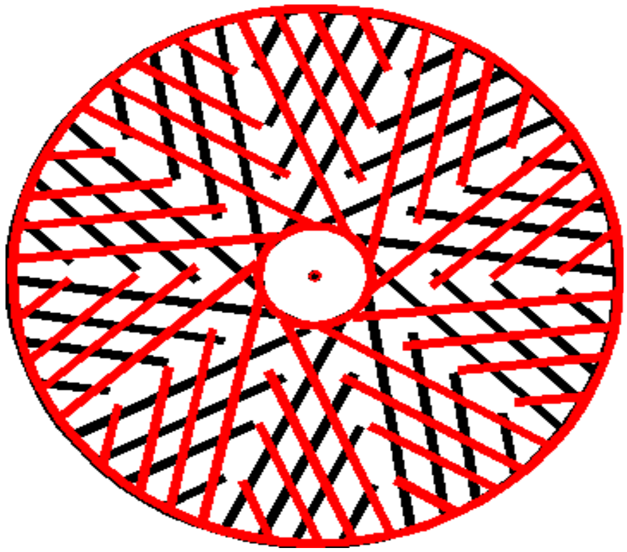


Figure 6 the pattern of runner and bed stones in red and black dresses, respectively (Source: Wheat Marketing Center)

6.2 Roller mill

The majority of flour is produced with roller mills. The metal or porcelain rollers were introduced in around 1870. Roller mills works very effectively. It removes the bran and germ, and reduce particle size. Figure 7 is the configuration of roller mill. Roller mills made the white flour for white bread affordable and popular. However, due to the loss of the germ, which is the major source of vitamin B, flour produced from roller mills require enrichment. The commercial roller mill has 3-5 break rolls and 5-10 reduction rolls. The milling process for cake and bread flour are similar but the sieve sizes for cake flour are smaller than those for bread flour.

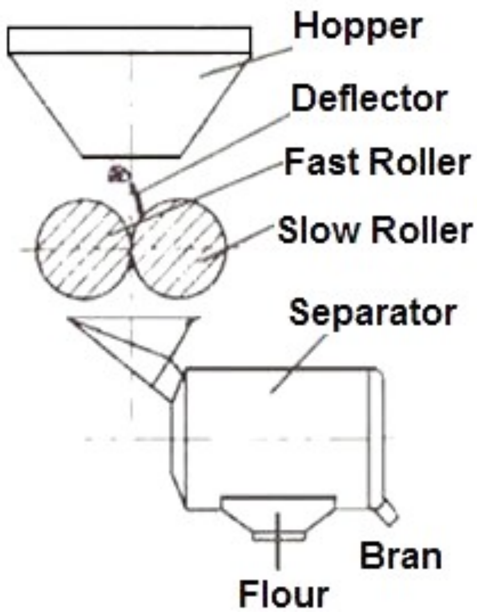


Figure 7 Roller Mill configuration

When roller mills are used for white flour production, grains are usually tempered before milling. The moisture for hard wheat after it is tempered is around 16.5% and soft wheat is 14.5%. Grain must be well tempered. If it is not tempered properly, the bran becomes brittle and it is easily broken into smaller pieces. This results in a higher ash content with a high correlation between protein and ash levels. If grain is tempered too long, bran is effectively removed, but ash content in flour may be too low. The roller mill process produces a final flour moisture of 12-14%.

Roller mills can also be used to produce whole grain flour. When producing whole grain flour, the grain is normally un-tempered and the resulting bran pieces are medium to coarse. Roller mill can be combined with other milling equipment to produce whole grain flour. In such situations, the grain can be lightly tempered. Pin-type or hammer mill may be used to further grind bran and the resulting bran pieces are fine to very fine.

6.3 Other mechanical mills

Whole grain flour can be made by hammer mill (Figure 9), pin-type (Figure 10) or other impact-type mill by itself.

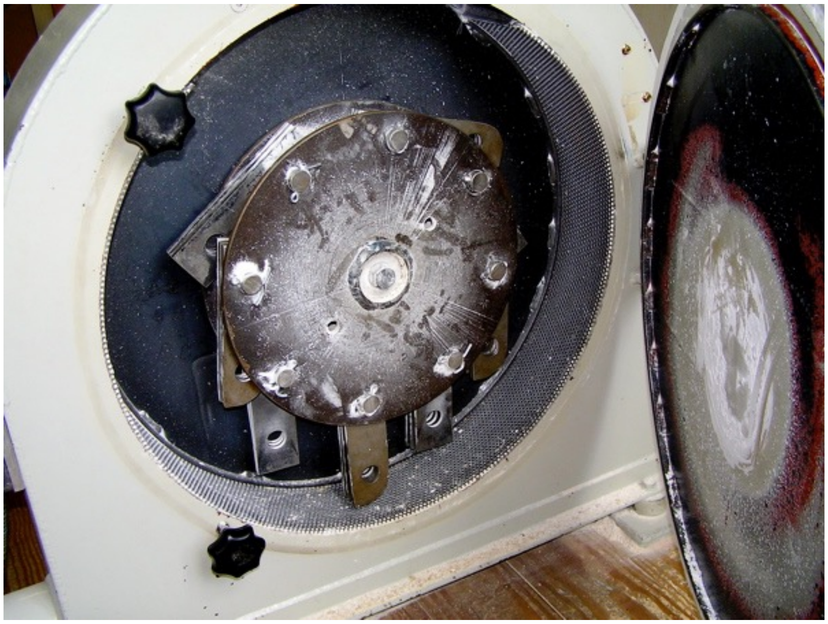


Figure 8 Hammer mill

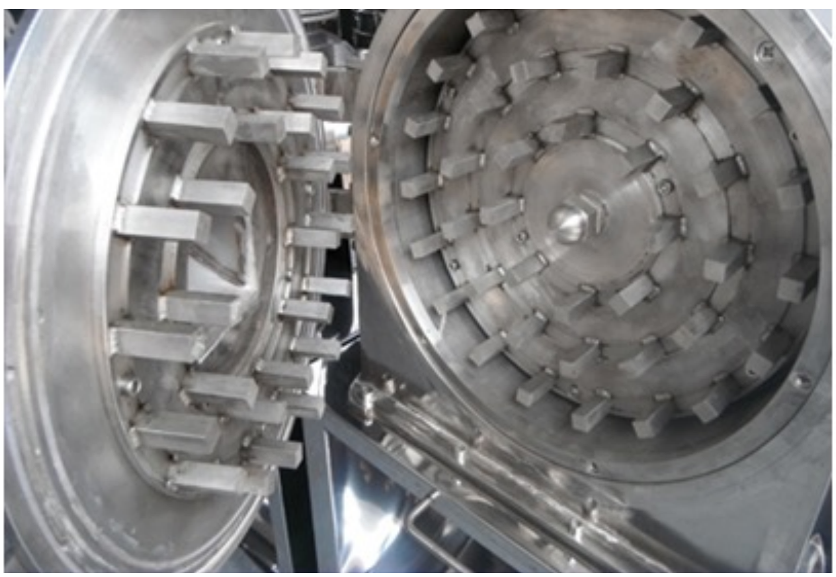


Figure 9 Pin-type mill

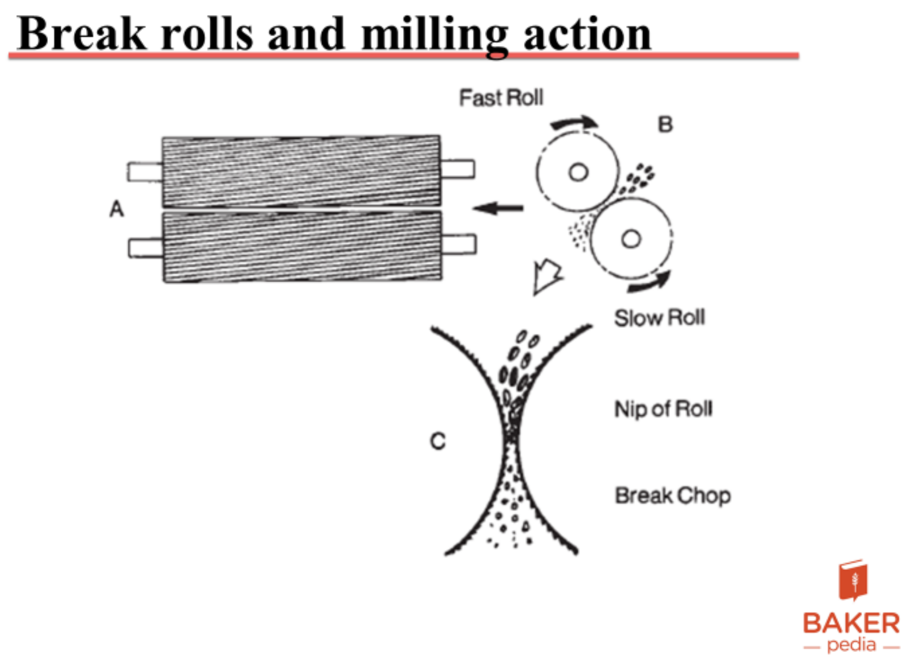


Figure 10 How the roller mill works

6.4 Simplified diagram for flour production (Figure 12)

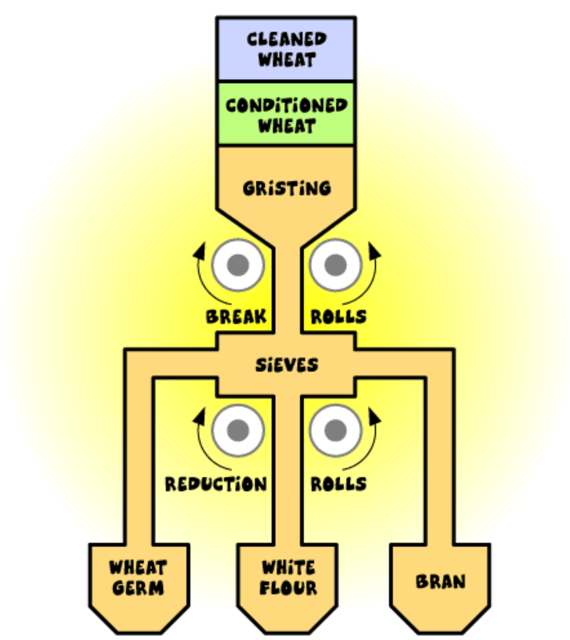


Figure 11 simplified diagram for four milling

7. Flour grade

7.1 Whole wheat flour (100% extraction)

7.2 Straight grade flour (70-75% extraction): all the flour streams milled, minus the bran and germ

7.3 Patent flour

7.3.1 Short patent (50-60% overall extraction) 60-70% of straight flour

7.3.2 Long patent: (65-70% overall extraction) 80-90% of straight flour

7.4 Clear flour is Left-over from straight flour minus patent flour. It can be classified as fancy, first clear and second clear flour.

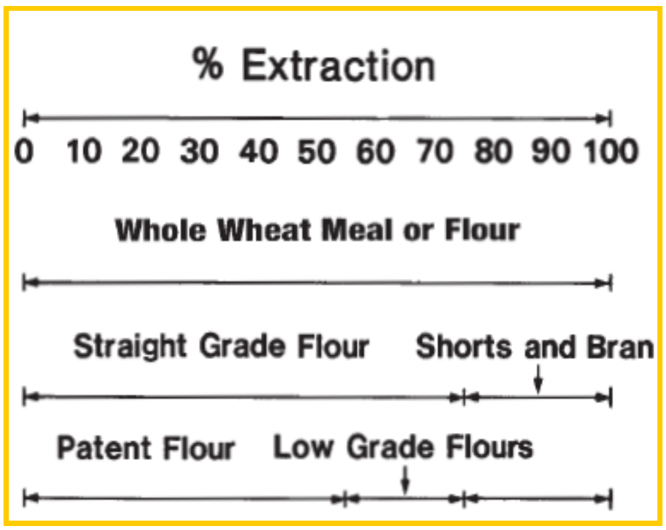


Figure 12 illustration of flour grade

8. Flour treatment

Chemicals or additives are used to enhance natural aging processes, and/or to improve flour quality. Normally treatment methods include bleaching, maturing, malting and enriching.

a. Bleaching

Bleaching is the process of removing yellow pigment (naturally found in flour) in order to produce white flour. Bran specks are not bleached. Benzoyl peroxide is usually used to bleach hard and soft wheat flours. This flour is usually labelled “bleached” and does not have an effect on baking performance.

b. Maturing

Maturing is the process of naturally or chemically aging flour. It is used for hard wheat flour. The aim is to strengthen dough forming properties and improve gas retention of gluten. It can also increase the bread volume. Potassium bromate, Azodicarbonamide (ADA), ascorbic acid and potassium iodate are usually used.

c. Malting

Malting is the addition of "malt" to flour to supplement naturally occurring enzymes in wheat. This would often be α-amylase from cereal or fungi. The purpose of these enzymes is to convert starch to dextrin and fermentable sugars.

d. Enriching

Enriching is the addition of nutrients to flour to replace the nutrients which were lost during the milling process. The enriched ingredients don't have effect on baking performance, except for the form of iron in some products. An example of flour enrichment is illustrated in Figure 13.

Flour Enrichment

	Enrichment (mg / kg)	
	Flour	Bread
Thiamin	6.39	3.96
Riboflavin	3.96	2.42
Niacin	52.86	33.04
Iron	24.05	27.53
Folic acid	1.54	0.95
Calcium	2114.54	1321.59

Figure 13 Example of flour enrichment

9. Flour composition

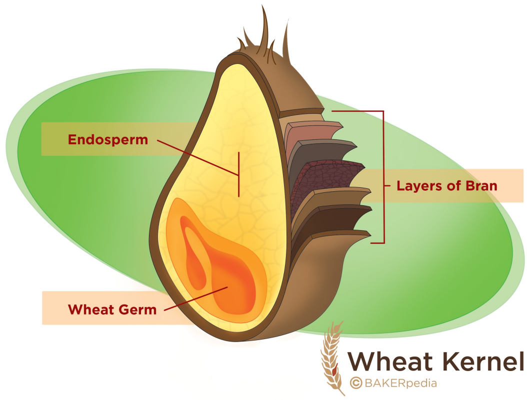


Figure 14. The structure of wheat kernel

9.1 Importance of flour composition

Flour is more than 50% of every baked formula. Its components affect water absorption, and the process of mixing, proofing, and baking. It also affects the bread volume. Understanding flour will help control process variation.

9.2 Starch

Starch accounts for more than 65% of flour. Starch includes native starch and damaged starch. Damaged starch accounts for around 10% in hard wheats. It can absorb 4 times more water. It is also susceptible to alpha amylase. Based on the difference of the structure, starch can be separated into amylopectin (Figure 15) and amylose (Figure 16). Amylopectin is highly branched. It accounts for 73% of starch (50% of flour weight). Amylose is a linear chain. It accounts for 23% of starch (15% of flour weight).

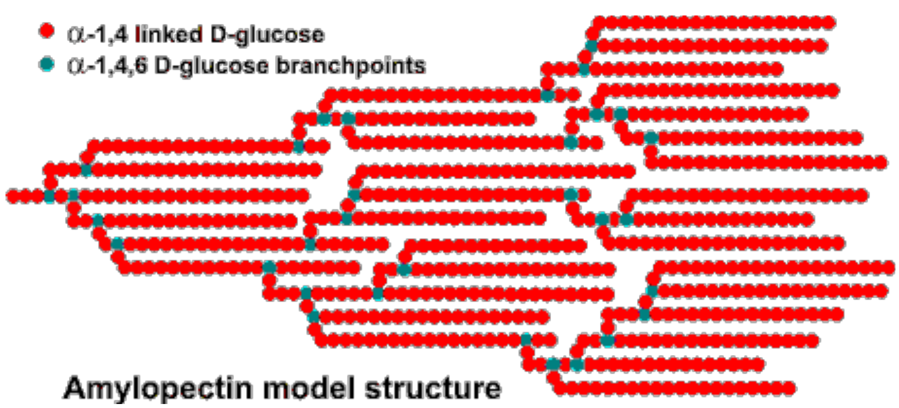


Figure 15 Amylopectin

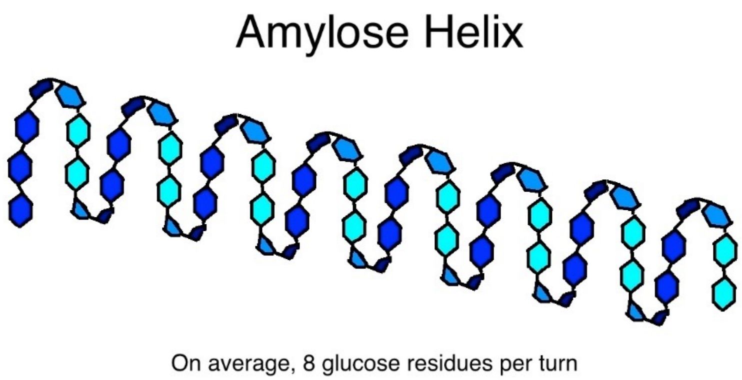


Figure 16 Amylose

9.3 Non-starch polysaccharides (pentosans)

Pentosans account for 2-3% of flour. In rye, pentosans makes up approximately 10% of the flour. It is derived from the cell wall material. 65% of pentosans are water insoluble and 35% are water soluble, forming gums upon interaction with water. The water soluble pentosans are able to absorb four times of their weight in water, which influences water absorption and viscoelasticity of bread dough.

9.4 Gluten

Gluten is the storage protein in wheat. It is elastic, viscous and extensible and is the main factor in water absorption of flour and dough functionality. Flour has 10-12% gluten. There are two kinds of gluten in wheat flour, the glutenin and gliadin (Figure 17). Glutenin is mostly hydrophobic. It has a larger surface area, is viscous and imparts strength. Gliadin is also hydrophobic. It is globular and contributes to extensibility.

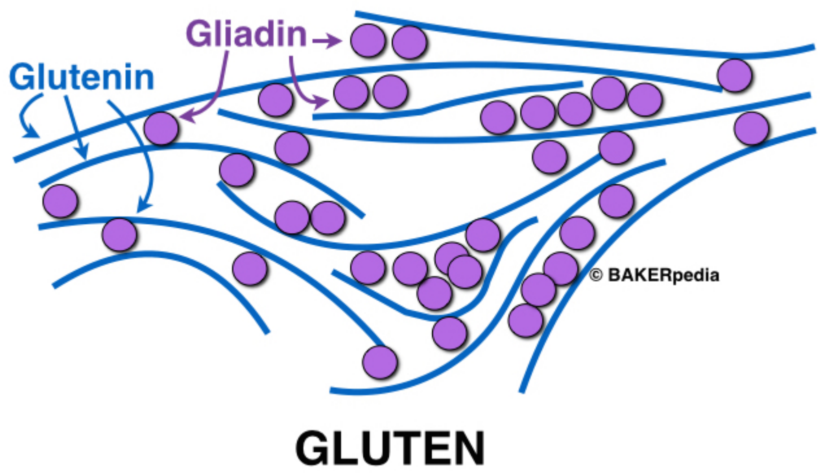


Figure 17 Illustration of glutenin and gliadin in gluten

9.5 Water soluble protein

Flour has 2-3% water soluble protein. They are mainly albumins and globulins. They affect water absorption and mixing properties. They also affects loaf volume and bread texture.

9.6 Lipid

Flour has 2.5% lipid. Among them, 1% is non-polar lipid, and 0.6% is galactosyl glycerides. That leaves 0.9% lipid as phospholipids. Lipid functionality in flour has little effect on water absorption and mixing. However, it has shown some effect on oven spring and texture of the final product.

9.7 Ash

The 0.5% of total flour weight is ash. Ash in flour is mostly from the bran. It doesn't affect water absorption or mixing. However, it could disrupt gluten formation, affect dough volume, and final color of the baked product. Ash can be used to measure the amount of bran in the flour, and is usually used as the indication of how well the product has been milled.

10. Attributes that can affect dough quality

10.1 Water absorption

Water absorption is the amount of water taken up by the dough to achieve the desired consistency. Protein, pentosans and damaged starch in flour are the main influences of water absorption. To measure water absorption, the farinograph, mixograph and mixolab are regularly used.

10.2 Different flour batch

Quality issues are big challenges in the baking industry. Several factors can contribute to the quality difference found in flour. They are issues from raw material, tempering, operators and processes.

10.3 High water absorption

Possible reason for high water absorption may include (1) more damaged starch, which increases mixing time and reduces volume (2) high protein quality and quantity.

10.4 High protein level

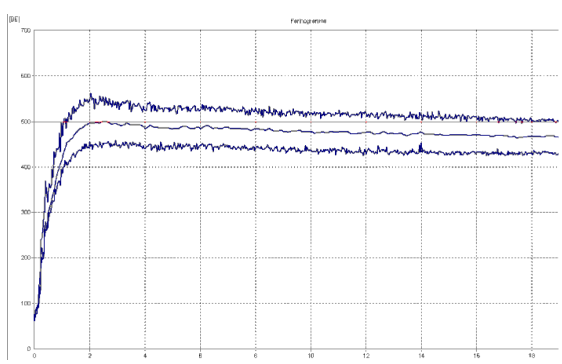
The high protein flour batch may have higher protein quality or quantity. If ash is also high, it the protein may have also come from bran particles.

10.5 Lower moisture level

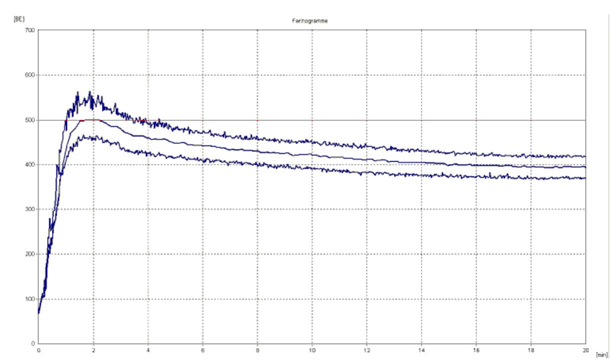
The lower moisture level in the batch of flour may be due to the inadequate tempering. This batch flour may have higher ash and may need more water.

10.6 Other factors

Factors that affect dough/batter quality include: (1) percent damaged starch (2) flour enzyme, i.e., amylase (3) oxidation requirements (4) milling characteristics, i.e., particle size (5) environmental & genetics



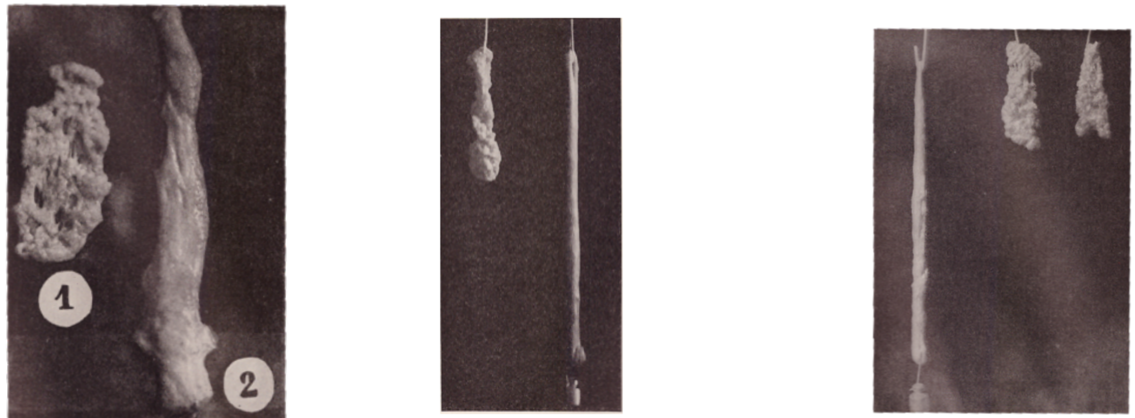
Hard wheat - stronger and higher level of protein



Soft wheat - weaker and lower level of protein

11. Aged flour

Flour aging also causes changes in flour properties. After flour is milled, its particle size is reduced and its internal components and enzymes are exposed to the environment. Biochemical (oxidatitive changes to lipids) reactions take place during flour aging. Examples are shown in Figure 18.



1) Gluten from aged flour
2) Gluten from freshly milled flour

1) Aged flour
2) Aged flour - Fat extracted

1) Freshly milled flour
2) Aged flour
3) Freshly milled flour + 0.75% oleic acid

Figure 18 Examples of gluten quality difference caused by aging the flour (Kozmin, NP. 1935. Cereal Chem 12:165)

12. How to manage flour variations

12.1 Enzymes

Enzymes and flour modifiers can be used to manage variations in flour. Enzymatic action changes dough properties. Amylase, protease, xylanase and lipase can increase dough extensibility. Glucose oxidase, lipoxygenase, transglutaminase and laccase can increase dough elasticity. Combinations of enzymes are common used and dough properties mush be checked after enzyme addition.

12.2 Flour modifiers

The four modifiers include oxidizing agents, reducing agents, emulsifiers, chlorine and bleaching agents. Oxidizers always strengthen dough. Azodicarbonamide, potassium iodate and calcium peroxide are fast oxidizers and ascorbic acid is a kind of slow oxidizer. Reducing agents always weaker dough. Cysteine breaks disulfide bonds for better alignment of gluten proteins. Bisulfite increases gluten extensibility for better sheeting, machinability. The non-ionic emulsifiers increase dough extensibility and ionic emulsifiers increase elasticity.

13. Flour specifications

These parameters are usually reported:

A. Moisture

B. Protein

C. Ash

D. Falling number

E. Rheological parameters (e.g. Farinograph)

    A. Water absorption
    B. Peak time
    C. Stability
    D. Mixing tolerance index

F. Solvent Retention Capacity (SRC)

G. Particle size (whole wheat flour)

H. pH (cake flour)

14. Flour analysis methods

14.1 Moisture: AACCI (AACC International Method) 44-01.01

Two to three grams of sample is heated at 130 ^{o}C for 1 hr.

14.2 Minerals: AACCI 08-01.01

14.3 Protein: AACCI 46-30.01

Combustion nitrogen analysis is used to analyze protein content in flour. Around 0.15-0.20 grams of sample is burned at 952 ^{o}C for 3 minutes.

14.4 Falling number: AACCI 56-81.03

Seven grams of sample is put in 25 ml of distilled water and the mixture is boiled at 100 ^{o}C.

14.5 Flour color: AACCI 14-30.01

Table 1 shows how flour color is evaluated.

Table 1 How flour color is evaluated

L* value	Whiteness	100 white
		0 black
a* value	Positive values	+60 red color
	Negative values	-60 green color
b* value	Positive values	+60 yellow color
	Negative values	-60 blue color

14.6 Glutomatic: AACCI 38-12.02

Glutomatic is measured by Perten Glutomatic System. It is the official world standard for gluten determining gluten quantity and quality.

Figure 19 Perten Glutomatic System

14.7 Farinograph: AACCI 54-21.01, ICC standard 115/1

Farinograph is used to measure flour water absorption and dough strength while dough is mixed. 50g-300g of flour is mixed with a certain amount of water. The mixing curve is recorded. Figure 20 is the Brabender Farinograph. Figure 21 a-c are farinograms.

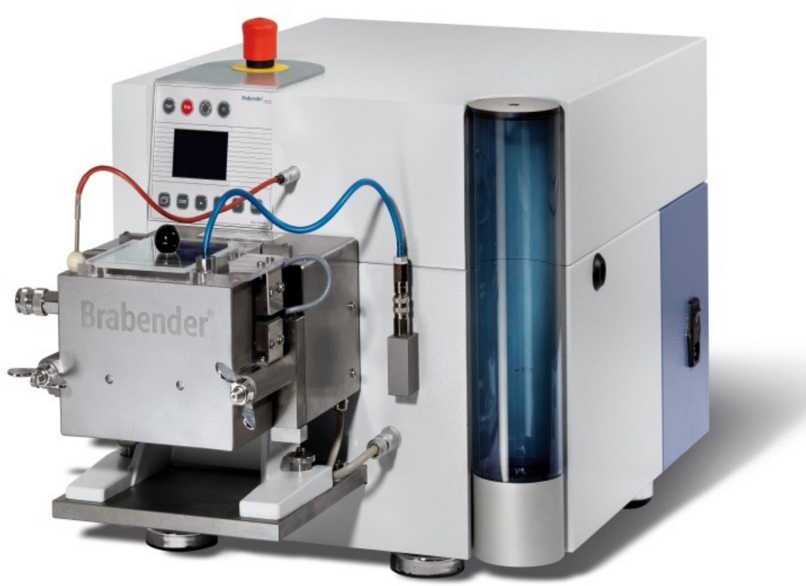


Figure 20 Brabender Farinograph AT

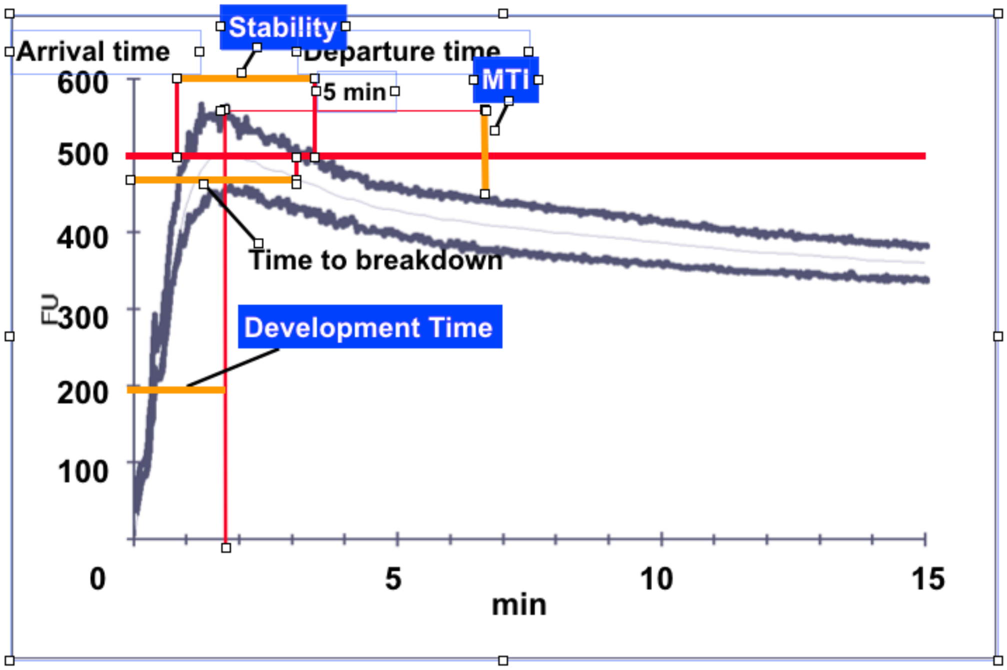


Figure 21(a)Properties of a farinogram

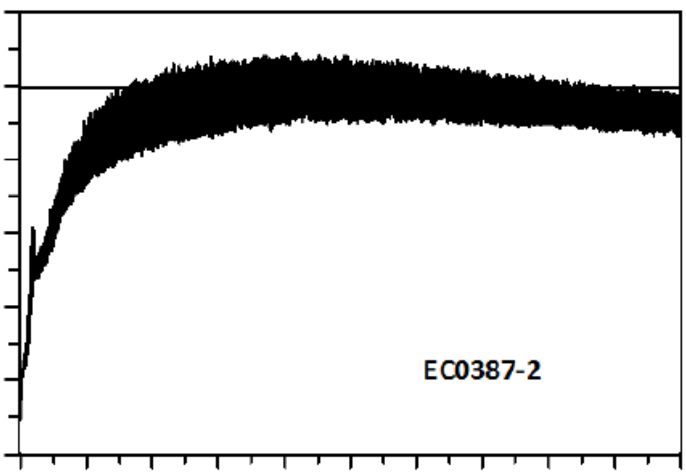


Figure 21(b) Strong Flour

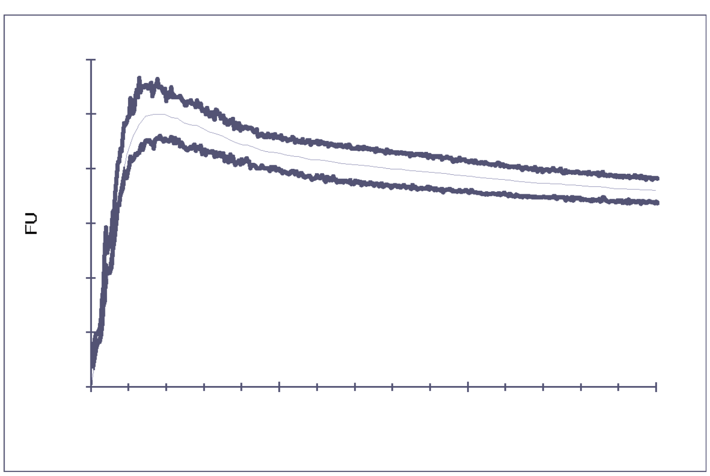


Figure 21(c) Weak Flour

14.8 Extensigraph: AACCI 54-10.01

Extensigraph is the visco-elastic recorder. It is used to measure dough extensibility and resistance to extension. Figure 22 is the picture for Brabender Extensigraph and figure 23 is the example of extensigram.

Figure 22 Brabender Extensigraph

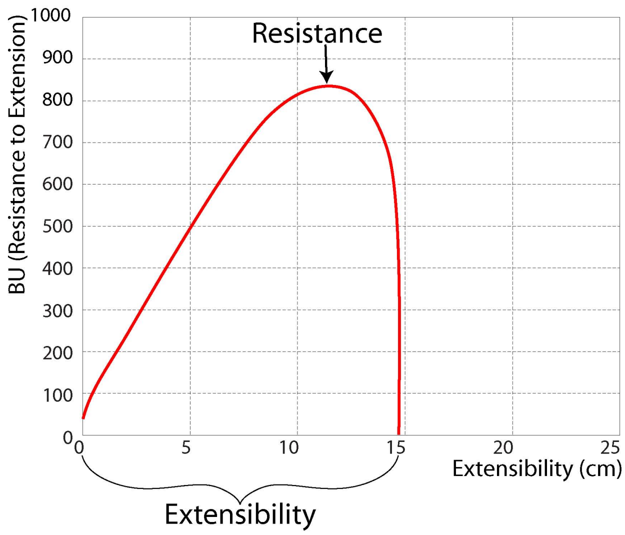


Figure 23 Example of extensigram

14.10 Alveograph: AACCI 54-30.02

Alveograph is another visco-elastic recorder. It is used to measure dough strength. Figure 24 is the picture of Alveograph. Figure 25 is the example of alveogram.

Figure 24 Alveograph

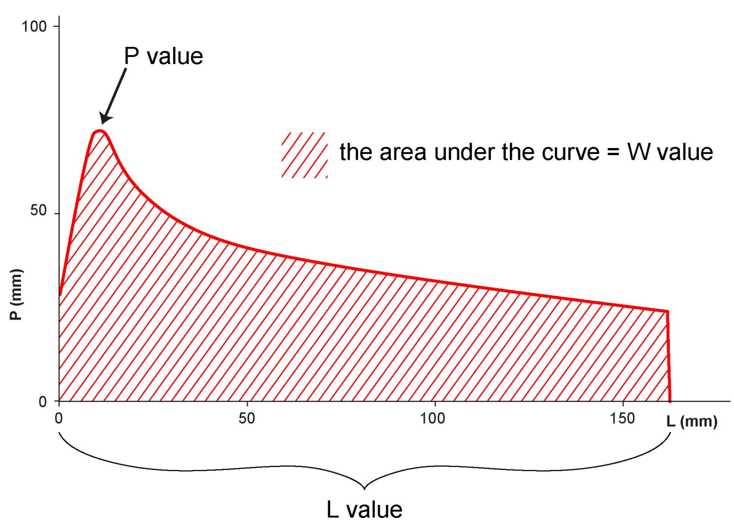


Figure 25 Example of Alveogram

14.11 GlutoPeak:

GlutoPeak is used to evaluate four performance. The 8.5 g flour is mixed with 9.5 g 0.5 M calcium chloride. Then stir the mixture at 1900 rpm for 5 min at 34 Oc. Figure 26 is Brabender GlutoPeak. Figure 27 is the example for GlutoPeak results.

Figure 26 Brabender GlucoPeak

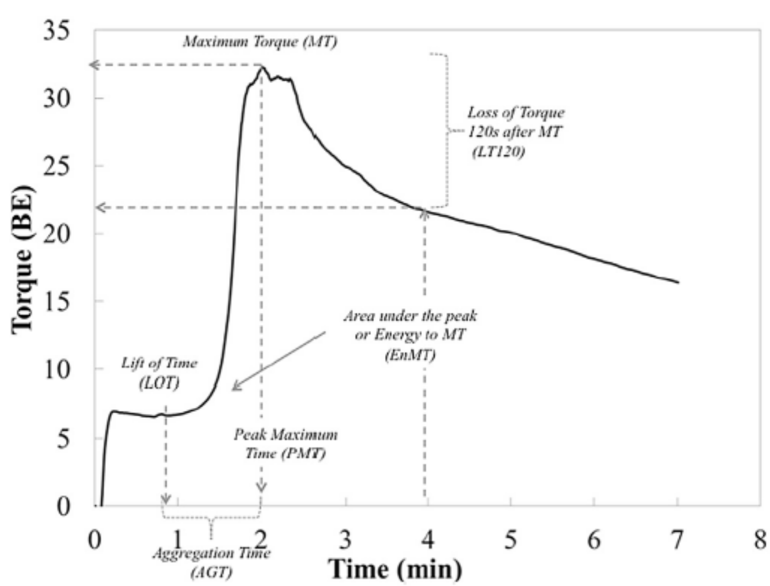


Fig. 1. Example of GlutoPeak curve of a winter wheat flour. The indices of importance are highlighted: lift of time (LOT), aggregation time (AGT), peak maximum time (PMT), maximum torque (MT), energy to MT (EnMT), and loss of torque 120 s after peak (LT120).

Figure 27 Example of flour Glutopeak results

14.12 Amylograph: AACCI 61-01.01

Amylograph is a viscosity analysis. It is used to measure flour starch viscosity change. Sixty-five grams of flour is mixed with 450 ml of distilled water. The mixture is heated from 30 to 95 °C and hold for 20 min. After that, the mixture is then cooled down from 95 °C to 50 °C. Figure 28 is the Brabender Amylograph. Figure 29 is the amylograph for sprouted what flour and sound wheat flour. Figure 30 is the typical flour pasting curve.

Figure 28 Brabender Amylograph

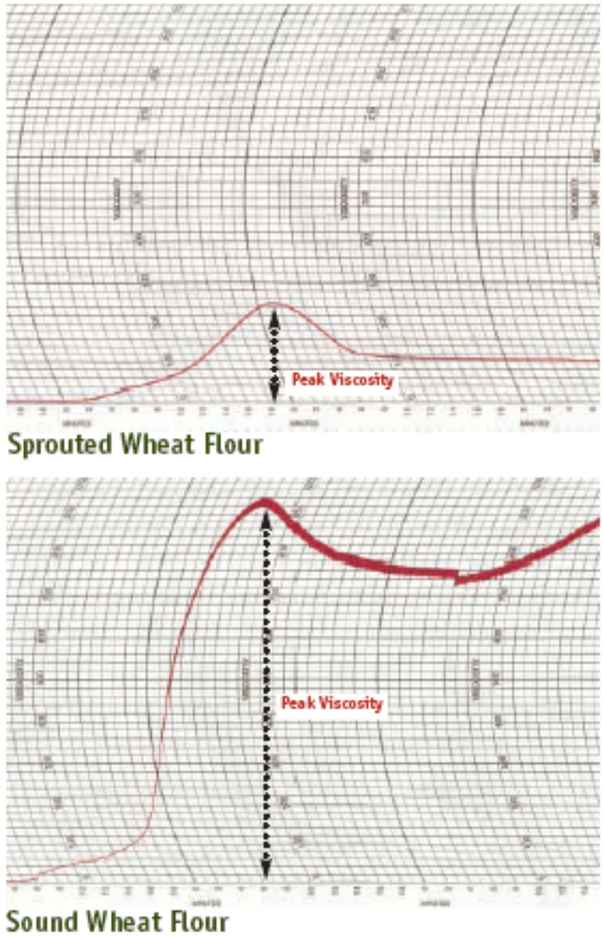


Figure 29 Example of flour amylogram

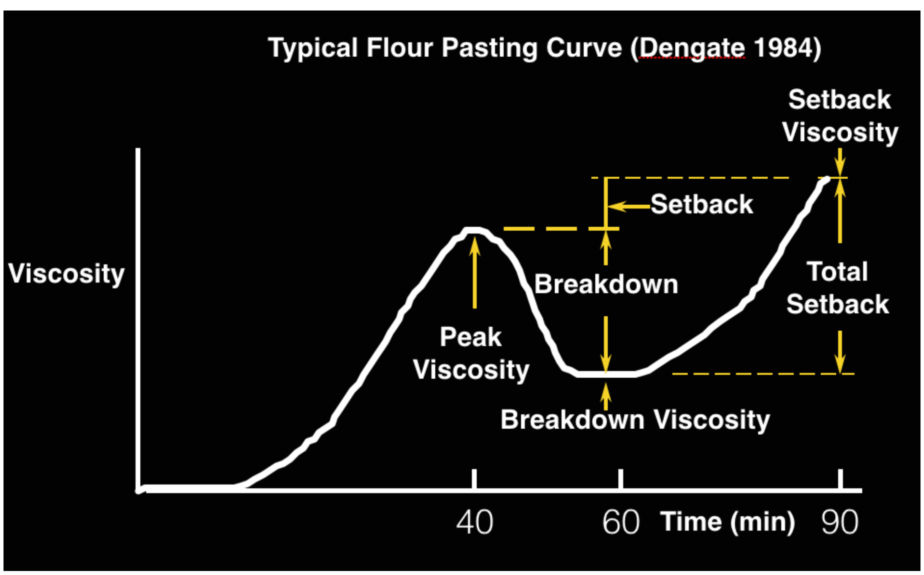


Figure 30 A typical flour pasting curve

15. Contributors:

Can gums extend the shelf life of cookies? Can whole grain dough really form a window pane? What causes the bubbles in cake? These are the types of questions Dr. Lin Carson, CEO of BAKERpedia, get everyday - driving her to her goal of building the world's biggest baking encyclopedia on BAKERpedia. A graduate of Kansas State University and Ohio State University, Dr. Carson has over 20 years in the baking and food industry, building technical service teams and programs. With past experiences at Wendy's Int'l and Dave's Killer Bread, Dr. Carson is now helping commercial bakers around the world streamline their quality processes to minimize waste and increase efficiencies. The Academy, is a hands-on learning experience at BAKERpedia. Dr. Carson launched The Academy series to meet the demands of busy bakers.

For the past 11 years, Mr. Junge led the bakery product category in Menu Innovation for McDonalds Corporation A graduate from Kansas State University with a MS in Grain Science. Raised in a family wholesale baking business that manufactured bakery products for 109 years, Mr. Junge has spent the last 36 years directing applied research applications in industry leading product development groups. His main focus throughout his career has been bakery new product innovation in the key markets for Grocery Products and Food Service. His experiences include directing product development groups at Continental Baking, Pillsbury, Schwan's and DuPont/Solae.

Dr. Gary Hou has conducted research projects on cereal products, and has presented numerous times at AACCI and IFT. He has authored or co-authored, and published more than 20 refereed research papers. With over 21 years at the Wheat Marketing Center, he is an expert consultant to the U.S. Wheat Associates and provided technical support and trainings to flour milling and food processing companies in over 30 countries. As a course director, he has taught numerous courses like “Asian Noodle Technology”, “Whole Wheat Flour Product Development”, “Flat Bread and Flour Tortilla Technology”, “Artisan Bread Baking”, “Cookie and Cracker Technology”, and “Frozen Dough Technology” to over 800 participants from over 20 countries. A graduate of Michigan State University and Jiangnan University, Dr. Hou is also an adjunct professor at the University of Minnesota and Oregon State University, advising and directing research on cereal products at these Universities. Dr. Hou has published “Asian Noodles: Science, Technology, and Processing”, the only English book providing comprehensive coverage on Asian noodles.

Dr. Jayne Bock is the Global Technical Leader of Food Applications for C.W. Brabender and is responsible for the research, development, and communication of food applications for Brabender instruments. She is an expert in gluten structure, whole grain applications, and end-use flour quality and continues to conduct research in these areas as an adjunct professor in cereal chemistry at the University of Guelph. She earned her B.Sc. and M.Sc. degrees at Kansas State University and her Ph.D. at the University of Wisconsin-Madison.