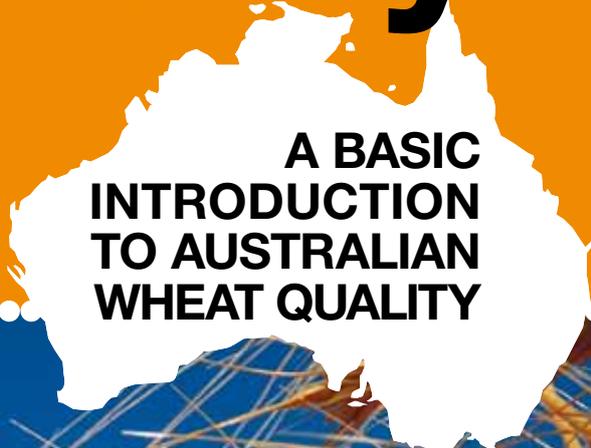


# Understanding AUSTRALIAN Wheat Quality



A BASIC  
INTRODUCTION  
TO AUSTRALIAN  
WHEAT QUALITY



WHEAT  
QUALITY  
OBJECTIVES  
GROUP

**GRDC**  
Grains  
Research &  
Development  
Corporation

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ISBN: 979-0-9775029-4-3

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First published September 2009

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**coretext**

Design and production:  
Coretext, [www.coretext.com.au](http://www.coretext.com.au)

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# Introduction

This publication has been prepared to provide an introduction to Australian wheat quality.

It is intended to be of interest to a wide range of audiences including those new to the wheat industry and those involved at various points in the wheat value chain, who need or wish to better understand the fundamental aspects of wheat quality.

In order for Australian wheat to be marketable both domestically and for export, it must be suitable for its intended end-uses. This publication provides information on the quality attributes that are important to achieving this goal.

There is a continuing need for wheat quality research to maintain existing standards, to introduce new and updated information and to identify novel traits, markets and end-use products. All this information must be available to wheat breeders so that new wheat varieties target the intended end-use of growers, marketers and consumers.

We are particularly keen that the publication is of value to growers as it will help to explain the quality factors inherent in the genetic composition of a variety, and those that are influenced by the environment.

While farm-gate return in dollars per hectare will always be a grower's key focus, choosing the variety that suits local growing conditions and is attractive to a range of buyers should help achieve maximum financial return.

This publication provides an insight into what factors are required to achieve a high-quality grade at the silo or the mill.



# Wheat and its place in the world

## (a) Introduction to the cereals – the cultivated grasses

Cereals are cultivated grasses that grow in temperate and tropical regions. They are classified as members of the Poaceae (or grass family) but they also display characteristics that allow them to be classified into tribes within the family.

Some common cereal groups are:

### Triticeae:

Wheat (*Triticum* spp), Barley (*Hordeum* spp), Rye (*Secale cereale*), Triticale (*Triticosecale*)

### Oryzae:

Rice (*Oryza sativa*), African rice (*O. glaberrima*), Wild rice (*Zizania palustris*)

### Aveneae:

Oat (*Avena sativa*)

### Andropogoneae:

Maize (*Zea mays*), Sorghum (*Sorghum bicolor*), Adlay (*Coix lacryma-jobi*)

### The triticeae group:

Triticeae comprise the most widely-grown and consumed group of the cultivated grasses. Its members include bread, durum (pasta or macaroni) and spelt wheat.

Examples of common cereal grains are shown in Figure 1.

## (b) Origin of the modern triticeae

Bread, durum and spelt wheat are all natural hybrids between wild grass species. The natural hybridization events that produced the triticeae grown today occurred between 7,000 and 10,000 years ago in the fertile crescent (an arc of countries extending from northern Egypt, through Israel, Palestine, Jordan, western Syria, south east Turkey and into northern Iraq) and their wild grass forebears still exist in the region and are valuable sources of new genes for wheat breeders.

The wild grass species are mostly diploids containing 1 set of 7 pairs of chromosomes. Two diploid grasses with different genomes (chromosome complements) naturally hybridized to produce a new plant type with 14 pairs of chromosomes. Tetraploids like them, the wild emmer wheat (*Triticum turgidum*) were the origins of modern durum or pasta wheat (*Triticum turgidum* ssp. *durum*). Further natural hybridization events occurred between domesticated emmer and another diploid grass (*Aegilops tauschii*) to produce plants with 21 pairs of chromosomes (hexaploids), giving rise to bread (*Triticum aestivum*) and spelt (*Triticum aestivum* ssp. *spelta*) wheat.



**Figure 1** Common cereal grains (anticlockwise from bottom) rice, oats, rye, barley, wheat and triticale and maize (centre).

PHOTO: T Westcott

## (c) Similarity across the cereal species

While there are structural similarities, wide variation exists among cereal grains in size and shape. One major distinction is the presence or absence of a surrounding hull when the grain is harvested, traded and processed. Most cereal grains (rye, wheat, triticale, sorghum and millets) are “naked”, that is free of hulls, while rice, and most commercial barleys and oats, are hulled.

The fruit of a grass is a caryopsis. It contains a single seed which accounts for the greater part of the entire fruit when mature. The seed comprises the embryonic axis, scutellum, endosperm, nucellus and testa or seedcoat, and is surrounded by the fruit coat or pericarp. The basic structural form of cereal caryopses is surprisingly consistent, to the extent that a generalized cereal grain can be described (Figure 2).

The embryonic axis and the scutellum together constitute the embryo. The embryonic axis is the plant of the next generation. It consists of primordial roots and shoot with leaf initials and is connected to and couched in the shield-like scutellum, which lies between it and the endosperm.

Cereal chemists use the term “germ” to describe all or part of the embryo, however, this is botanically incorrect. The correct botanical description of the embryo is as given above whereas the cereal chemist term “germ” refers to the embryo-rich fraction produced during milling.

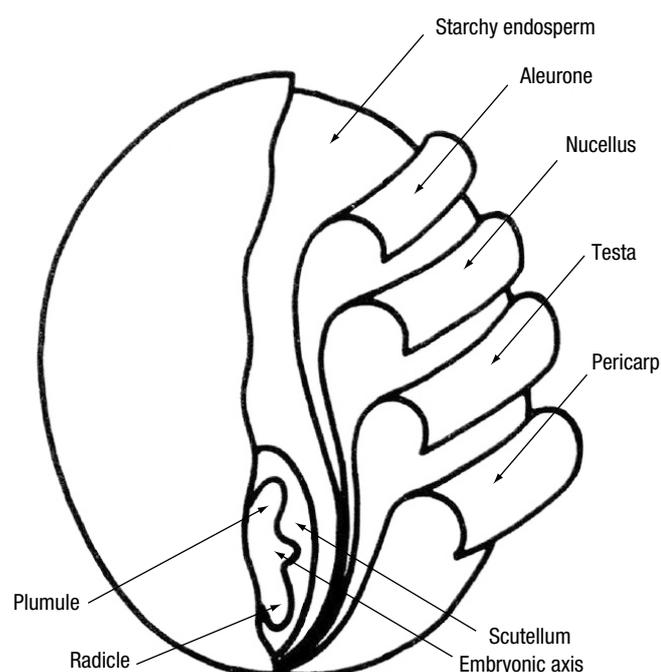
### (d) The evolution of wheat-based foods

Modern wheat has evolved from primitive forms first harvested and cultivated in the Middle Eastern region many centuries ago. Wheat-based foods were prepared in different ways by different cultures but most products would have been unleavened or naturally fermented.

Consumption of wheat spread from Palestine to Egypt and from Northern Mesopotamia to Iran where bread was first developed. Bread wheat then spread from Iran to Southern Mesopotamia, India and Russian Turkistan and from there to China and Southern Russia. The chronology of these movements is uncertain, however, there is archaeological evidence of emmer, a primitive wheat type, in Iraq as early as 10,000 BC.

Drawings from Egyptian tombs from about 2500 BC show farm activities indicating that emmer was grown and harvested in Ancient Egypt.

The Etruscans developed hand-made pasta and its manufacture is depicted in tombs near Rome built in the 4th century BC. The process was eventually handed down to the Romans and still exists today. The Etruscans seemed to have sourced their grain locally but the Romans brought their wheat mostly from Egypt and Sicily where durum wheat appears to have been cultivated.



**Figure 2** A schematic representation of a generalized cereal caryopsis.

SOURCE: Kent and Evers, 1994

By 1700 BC, wheat had a role in the Chinese diet. The ancient Chinese ground wheat in a stone mortar to make flour. There is evidence that noodles were made during the Han Dynasty, 206 BC to 220 AD, and were extremely popular in the Ming Dynasty, 1368-1644 AD, when they were first called *mian*. Noodles have continued to evolve since that time and many types exist today. The Chinese also developed steamed breads, steamed buns and dumplings.

Today, in the Middle East, traditional flatbreads are fast baked in very hot ovens, however, they were originally baked on hot stones around open fires. Similar techniques were used in Central Asia and the Indian Sub-continent.

In Europe the use of yeast-fermented loaf-type breads has predominated resulting in a myriad of styles seen today throughout the entire region.

In Eastern Europe and Scandinavia, many breads are produced by the sour dough process with or without the inclusion of rye flour in the formulation. Most of the bread is produced as small loaves or rolls. In Southern Europe (Italy) rather robust and chewy breads, *pane di casa*, are baked in wood-fired ovens.

The development of pan breads occurred in Britain. Yeasted dough was baked in an open metal tin which determined the shape of the loaf. This eventually led to the development of lidded tins and the popular “sandwich loaf” that used today.

### (e) Similarity of products around the world

As a result of the unique properties of wheat flour dough, distant populations independently developed similar wheat-based foods. Dumplings, which use thin dough sheets to enclose fillings, are quite popular in China. Similar types of dumplings are also consumed in Japan and Korea. Other types of dumplings are popular in many Eastern European countries. Various types (*pelmenti*, *pierogi*, *knödel*, *kulduny*) exist in Russia and countries from the former Soviet Union, Hungary, Poland and Germany. *Kreplach* are the Jewish version of these Eastern European dumplings.

The Italians use sheeted dough to make *lasagne*, *ravioli* and *cannelloni*.

In the north of China, thin-sheeted flatbreads called “bing” are popular. Peking Duck pancakes are a type of bing and *shaobing* is a thin-pocketed bread that can be stuffed with savoury fillings. These breads are similar to some Middle Eastern flatbreads and Mexican *tortillas*.

Chinese steamed breads (*mantou*) and filled steamed buns (*bao*) bear similarities to the boiled dumplings made in some European countries.

Some European noodle and pasta products bear a striking similarity to the texture and appearance of Chinese white salted noodles.



# Fundamentals of wheat quality

## (a) The wheat value chain and the three basic quality determinants

The wheat value chain is shown in Figure 3. The driving factor is the relationship between all involved, and the need for each level in the value chain to respond to the needs of others while being able to extract value in a commercial environment. Ultimately, the value chain is consumer driven.

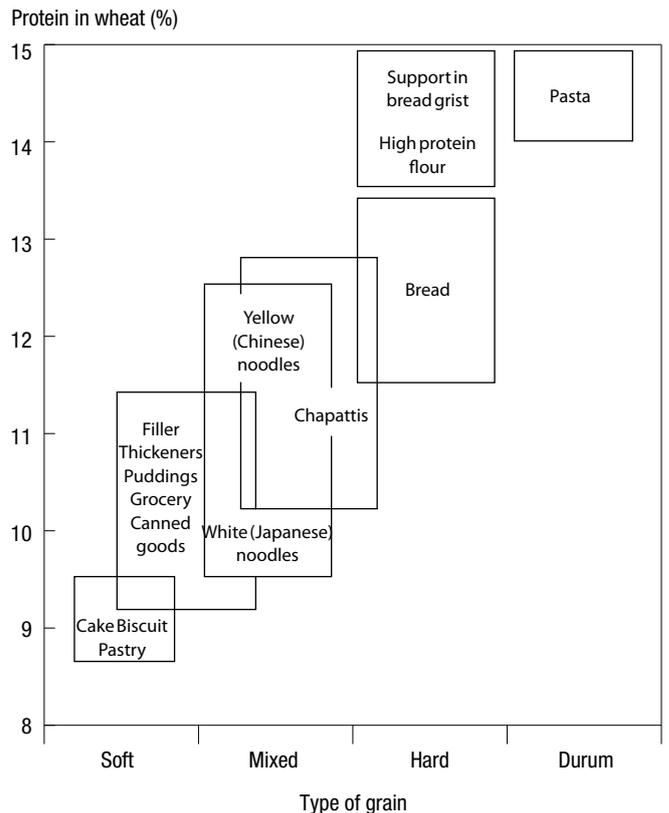
Wheat quality is complex and has different meanings at each step of the value chain. To some, quality merely equates to price; to others, it is the complexity of the genetics and processing systems used to produce the diverse range of flours needed to manufacture the seemingly endless array of end products demanded by consumers.

At its most basic level for processing into end products, wheat quality can be broken down into a few fundamental components. Not surprisingly, these components are the basis for world wheat trade and the grading systems countries use to provide grain to the trade.

Three factors – grain hardness, grain protein content and dough or protein quality aspects – explain most of the variation in wheat quality. The inter-relationship between these three basic factors, which are all defined in later sections, is summarized graphically in Figure 4.

For production of a quality end product, there is a relatively-narrow range of grain protein content within a hardness type. Across the total end product range, good dough handling characteristics are required for the manufacture of good quality end products. Also inherent in the graphic is a “protein quality” or dough strength, which must increase with grain protein content. Higher dough strengths are required within hard grained wheat for the production of breads, than for some types of noodles.

**Figure 4** The relationship between grain hardness, grain protein content and end products.



SOURCE: Moss, 1973

**Figure 3** The consumer driven wheat value chain.



## (b) Quality fundamentals – the role of genetics and the environment

One of the aspects contributing to the complexity of wheat quality is that its expression as measured through a range of analytical tests is the result of genetics, the growing season environment and the interaction between the two, known as genotype x environment (G x E) interaction. These effects on wheat quality are summarized in Table 1.

## (c) The concept of protein content versus protein quality

Grain protein content in the mature grain is largely determined by environmental and farm management factors, with genetics playing a minor role in being either low or high in protein content. By contrast, protein quality is determined by the genetic composition of the wheat variety and also how the environment influences genetic expression.

It is always important to be clear about whether it is protein content or protein quality that is being considered.

**Table 1** Some important wheat quality measures influenced by genetics, the environment and G x E interaction.

| Genetics  | Environment                                       | G x E interaction     |
|---|---|-----------------------|
| Protein quality, dough strength and stability   | Grain protein content                             | Grain protein content |
| Grain hardness                                  | Grain plumpness and test weight                   | Screenings levels     |
| Milling yield                                   | Weather damage effects (like frost and sprouting) | Test weight           |
| Grain colour                                    | Screenings levels                                 |                       |
| Pre-harvest sprouting tolerance due to dormancy | Grain moisture content                            |                       |

### (i) Protein content

Protein content is important as it is one of the key criteria on which international wheat trade is based. Buyers use protein content as an indication of the potential end-uses of a parcel of wheat. Wheat breeding and variety classification are both critical in maintaining the linkage between protein content and end-use quality so that buyer's expectations are fulfilled.

Buyers also use protein content to indicate suitability for most end-uses. It is the protein component in flour that, when hydrated by the addition of water and mixed and or kneaded, forms a continuous network of gluten. It is the gluten network that provides the cell structure to a loaf of bread. The quality of the gluten can have a substantial effect on bread loaf volume, appearance and consumer acceptance. Similarly, gluten provides the structure to sheets and strands of noodles with the level of protein in the flour having a pronounced effect on the texture or mouth-feel of cooked noodles. There is an optimum range of protein content for most end-uses of Australian wheat.

### (ii) Protein quality

The quality of wheat protein is a more difficult concept than that of protein content as it includes the proteins involved in the formation of gluten and the properties of gluten.

The first classification of wheat proteins was according to their solubility. Albumins were water soluble, globulins were salt soluble, gliadins alcohol soluble and the glutenins were divided into acid soluble and acid insoluble fractions. The total acid insoluble fraction of glutenin contributes significantly to dough strength and baking quality and the gliadin fraction to dough extensibility.

Today end-users apply a range of measurements, from the determination of the actual amount of gluten in flour, through to the assessment of the viscoelastic properties of a dough. Irrespective of what is measured, inevitably protein quality is related to dough functionality and the suitability of flour for end-product processing.

A suitable balance of acid insoluble glutenin and gliadin, in combination with a particular level of total protein, is needed for most flour end-uses.

### (d) The relationship of the basic quality components to international grain trade and grading systems

When the three basic components of protein content, grain hardness and protein quality are combined with grain colour (red versus white) and production region (spring wheat areas compared with winter wheat areas), immediately the basis on which the major exporting nations name their principal grades of wheat is set. For example, two major competitor grades to Australian wheat, Canada Western Red Spring Wheat (CWRS) and US Hard Red Winter Wheat (HRWW) typify the use of grain colour, production region and grain hardness in their names.

Australia produces only white grained wheat, and while region is not used in a grade name, just how Australia uses production region to meet the needs of its customers will be addressed in a later section.



# World and Australian wheat production

## (a) The major producing and exporting countries

Australia usually ranks between 6th and 8th in total annual average wheat production with countries like the Russian Federation, the US, India, China and the EU-27 countries producing between 2 to 6 times more annually (Table 2). However, Australia ranks 4th among the major exporting nations and the fact that as much as 80%, on average, of the national crop is exported has a major influence on the operations of all sectors of the Australian wheat value chain.

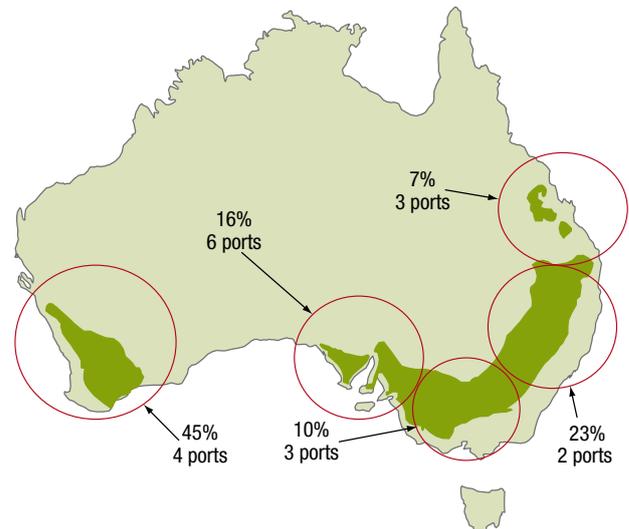
A key feature recognized by importers of Australian wheat has been its quality. Initially this was limited to its physical quality attributes such as low moisture content, cleanliness, and freedom from infestation, but this has now extended to processing capabilities and suitability for end-use.

## (b) Wheat production in Australia

Wheat is the largest grain crop grown in Australia. Most of the crop is made up of spring varieties that are sown in autumn to early winter and which mature in late spring to early summer. Small areas of winter wheat are produced in the higher rainfall areas of southern NSW and Victoria.

Grain is grown in all Australian states, but primarily in a narrow crescent known as the wheat belt (dark shaded areas in Figure 5). The location of the wheat belt is largely determined by average annual rainfall.

This wide geographical distribution means that growing areas are subject to markedly different climatic conditions and soil types. These features act to lessen the consequences of adverse climatic conditions on the overall national crop, although there is still some degree of



**Figure 5** Map of the Australian wheatbelt with the number of export ports and the percentage of average production shipped through those ports.

SOURCE: AWB

volatility in national production from year to year with drought seasons reducing production to less than 10 million tonnes.

Harvesting commences in Central Queensland in August-September and progresses down the east coast, finishing in Victoria and South Australia by mid January. In Western Australia, harvest generally commences in early November and is completed by mid January.

Over the past 5 years (2002-03 to 2008-09), Australian production has averaged 18,368,000 tonnes (Table 3), but over the past 20 years, production has varied between 9 and 25 million tonnes per annum, with the average being 16 million tonnes annually.

Australia has been unique internationally in that the grain-handling systems and the marketing of grain were either grower owned, or managed by boards dominated by growers. This strong grower role, was combined with (a) predominantly dry weather at harvest time, (b) potential problems with grain insect infestation during storage and (c) the logistics of storage, handling and transport to ports for

**Table 2** Five-year average wheat production, 2004-05 to 2008-09, for leading producing nations and major exporters and importers.

| Major producers      | '000s tonnes   | Major exporters    | '000s tonnes   | Major importers | '000s tonnes   |
|----------------------|----------------|--------------------|----------------|-----------------|----------------|
| EU-27                | 134,765        | United States      | 28,451         | Egypt           | 7,744          |
| China                | 104,032        | Canada             | 17,122         | Brazil          | 6,432          |
| India                | 72,870         | EU-27              | 15,117         | EU-27           | 6,380          |
| United States        | 57,801         | Australia          | 12,546         | Japan           | 5,632          |
| Russian Federation   | 50,220         | Russian Federation | 11,325         | Algeria         | 5,450          |
| Canada               | 24,895         | Argentina          | 10,007         | Indonesia       | 5,208          |
| Pakistan             | 21,438         | Kazakhstan         | 5,665          | South Korea     | 3,621          |
| Australia            | 18,378         | Ukraine            | 4,983          | Iraq            | 3,602          |
| Ukraine              | 18,000         | Turkey             | 2,176          | Mexico          | 3,522          |
| Turkey               | 17,360         | China              | 1,937          | Egypt           | 7,744          |
| <b>Global totals</b> | <b>627,123</b> |                    | <b>116,893</b> |                 | <b>114,141</b> |

SOURCE: USDA PSD from [www.fas.usda.gov/psdonline/](http://www.fas.usda.gov/psdonline/)

**Table 3** Australian average wheat production ('000s tonnes) 2002-03 to 2008-09.

|              |               |
|--------------|---------------|
| Queensland   | 1,250         |
| NSW          | 4,732         |
| Vic          | 1,762         |
| Tas          | 29            |
| SA           | 2,446         |
| WA           | 7,356         |
| <b>Total</b> | <b>18,368</b> |



PHOTO: L Derrett

**Figure 6** Sampling wheat at delivery.**Table 4** Receival standards for Australian Milling Grade wheat.

|                                      |   |
|--------------------------------------|---|
| Test weight                          | Minimum of 74 kg/hl   |
| Moisture content                     | Maximum of 12.5% w:w basis  |
| Screenings (2 mm screen)             | Maximum of 5% w:w basis   |
| Unmillable material above the screen | Maximum of 0.6% w:w basis   |
| Sprouting                            | NIL, in absence of falling number testing                                     |
| Falling number                       | Minimum for 300 secs for all grades except APH (350 secs) and AGP (200 secs). |
| Live insects                         | NIL   |

**Figure 7** Examples of grain storage systems in Australia.

PHOTOS: L Derrett

export. Consequently, most of the grain was delivered within a few days of harvest. This necessitated the development of systems by growers and grain receivers to assess the quality of every load of grain delivered to every receival point across the country. Development and refinement of receival standards for Australian milling grade wheat (Table 4) are fundamental to the quality of Australian wheat.

Assessment of the basic quality parameters listed in Table 4 needs to be rapid and reliable. Speed and accuracy were essential so that receipt of grain was not slowed by the need to test and growers were paid correctly for their grain. Testing had to be capable of being conducted under the harsh, hot, dry and dusty conditions that prevail at grain receival points. Use of mechanical devices to sample truck loads of grain (Figure 6), assess them for screenings percentage, test weight and protein content were deployed across the country. When rain events occurred at harvest time, Falling Number machines were also used to assess sprouting levels.

A wide array of different types of storages exist, from vertical concrete silos to horizontal sheds to the cheaper to erect, but expensive to operate, bunker storages and grain bags. Some of these are shown in Figure 7.

### (c) White grained versus red grained wheat

Wheat is categorized in the international grain trade by its seed coat colour. There are two distinct types, red grained wheat and white grained wheat (Figure 8). Australia is unique amongst international wheat exporters in that it only produces white grained wheat for milling purposes.

In 1923, the Interstate Conference of Ministers of Agriculture took the decision to discourage the growing of red wheat in the Commonwealth. The decision was driven by the concerns of Great Britain, a major market at the time and taken under threat of a penalty should red-grained varieties be detected in shipments. Today that decision sees Australian white wheat preferred in certain markets ahead of the red wheat mostly grown by our major competitors. This strong customer preference has seen major competitor countries like Canada and the US attempt to develop sufficient quantities of white wheat to compete in the highly demanding, quality conscious markets of Asia.

Both red and white wheat have advantages and disadvantages. Red wheat is predominantly produced in the Northern Hemisphere where the harvest period is late summer to autumn. Rain events often interrupt harvest so grain dormancy becomes an important attribute conferring sprouting tolerance. White wheat does not possess the same tolerance to pre-harvest sprouting and tends to be grown in regions where the likelihood of rain at harvest is lower.

Red wheat produces dark and quite bitter bran which limits its use for whole wheat products and for products using flour that requires a bright and white appearance, like noodles, dumplings and steamed breads.

The bran from white wheat does not impart a bitter flavour to grain products and any bran specks that get into the flour are less noticeable. Thus white wheat can be milled to higher flour extractions without the deleterious effects of bran contamination. Flours produced from Australian white wheat are ideal for producing Asian products such as noodles, dumplings and steamed breads where a bright, clean external appearance of the final product is paramount.

PHOTO: T Westcott

**Figure 8** Wheat seed coat colour. White wheat (left) and red wheat (right).



# Grading systems

## (a) The concept of grading

Grading is a means of segregating wheat exhibiting different attributes such as grain hardness, grain colour, protein content and the different dough strengths needed for various end products. Grading is also used by grain buyers and traders to separate sound wheat, suitable for human consumption, from weather damaged and disease or drought-affected grain of lesser value.

Traditionally, when small distinct parcels of grain were traded, grading was limited to the visual appearance and smell of the grain (to identify weather effects), the presence of diseased grain, other contaminants, and the extent of the inevitable insect infestation.

As grain trading became more sophisticated, buyers demanded to know more about the grain they were purchasing. This resulted in the use of the bushel measure, which is the weight of grain that would fill a container of 8 imperial gallons. This type of measure, now metricated to hectolitre weight (weight of 100 litres of grain), is referred to as test weight and is still regarded as a reliable indicator of overall wheat quality. It reflects the growing conditions and stresses that the wheat plant has endured during its development, including drought, leaf, stem and root diseases, frost, heat stress, and rain during grain filling, maturation and the immediate pre-harvest period.

Modern grading systems satisfy a number of key criteria. First, they must have commercial relevance and clearly reflect the value of the grain to the end-user. In the case of wheat, this requires the application of standards which exclude deleterious factors such as sprout damage and contamination with noxious weed seeds and include standards for physical characteristics, milling performance, protein content and water absorbing capacity of dough. These standards indicate the suitability of the grain for the production of flour for particular end-uses.

Second, any grading system must be simple to apply at all grain receival points, using rapid, reproducible and robust testing methods. This is particularly important in the Australian context, where the vast majority of the annual crop is delivered to either the central bulk grain handling system or private on-farm storage over roughly a 3-week period. Because this highly concentrated delivery period coincides with the hottest part of the summer, the testing methods must perform satisfactorily in the hands of relatively unskilled operators and casual staff, working under extreme conditions of temperature and high grain throughput.

Third, and most important, the standards being applied must be readily achievable by farmers in their production regions in order to meet the first criterion of commercial relevance of the grain to potential end-users.

## (b) The Australian grading experience

The Australian approach to wheat-grade determination has differed to that employed in the US and Canada. Commercially, a grade is awarded after a load has been sampled and tested according to the receival standards, including variety classification, protein content, test weight, screenings and sprouted kernel levels, and, for clarity, this is best described as a Commercial Grade. The Australian system is relatively simple in that all of the milling grades of wheat have a white seed coat and are grouped into two broad categories based on a difference in grain hardness. Deliveries deemed to be unsuitable for human consumption, due to pre-harvest weather damage, disease effects, contamination with weed seeds or other non-wheat grains, are stored separately and used for animal feed or industrial purposes.

**Table 5 Australian wheat grades, their defining attributes and major end-uses.**

| Grade           | Attributes   | End-uses   |
|-----------------|--|--|
| Prime Hard      | Minimum protein content of 13%<br>Hard-grained varieties<br>Prime hard varieties<br>Excellent milling quality<br>High dough strength and functionality | High volume pan bread and hearth bread<br>High quality yellow alkaline and dry white salted noodles                    |
| Hard            | Minimum protein content of 11.5%<br>Hard-grained varieties<br>Superior milling quality<br>Good dough strength and functionality                        | High volume pan bread, flatbreads and noodles  |
| Premium White   | Minimum protein content of 10%<br>Hard-grained varieties<br>High milling performance   | Noodles, including instant noodles<br>Middle Eastern and Indian-style flatbreads<br>Pan bread<br>Chinese steamed bread |
| Standard White  | Protein content less than 10% unless Australian Standard White classification  | Multipurpose (flatbread, steamed bread, noodles)   |
| Noodle          | Protein content 9.6-11.5%<br>Soft grained varieties<br>Very good noodle quality  | Dry white salted noodles and Japanese udon noodles   |
| Durum           | Very hard grained varieties<br>Good semolina yield<br>High yellow pigment levels   | Pasta and couscous   |
| Soft            | Soft grained varieties<br>Maximum protein content of 9.5%<br>Weak doughs with low water absorption   | Biscuits, cakes and pastry   |
| General Purpose | Wheat that fails to meet higher milling grain receival standards, or with Australian General Purpose classification                                    | All purpose flours<br>Blending applications  |
| Feed            | Wheat suitable for animal feed, including all red grained varieties.   |  |

The US and Canada grading systems are considerably more complex using geographic separation of the major production regions, as well as grain colour and wheat type (winter versus spring) to name major wheat classes. They have also adopted complex grading systems based on kernel density (test or bushel weight) and a range of other physical quality criteria, further contributing to the challenges faced by the grain handlers having to cater for a myriad of classes and grades of wheat.

In Australia, deliveries suitable for human consumption are also segregated and stored according to variety and protein content into grade based parcels (Table 5). In addition, the quality of a variety at a given protein content is used to define its suitability for certain end-uses and is fundamental to the operation of the grading system. Only varieties that meet basic protein content-processing quality criteria are eligible for receipt into specific grades.

In international wheat trade circles, protein content is considered one of the single most important quality factors used in determining the value of wheat, and, along with variety, is one of the cornerstones of the Australian grading system.

The Australian system of grain receipt and payment has been gradually refined since the early 1970s. Payment for quality was introduced in 1989 based on payments of \$3/percent protein/tonne applied to Australian Standard White (ASW) deliveries between 9.5 and 11.0% protein. This was the first real breakdown of the established practice of paying all growers of ASW wheat, the same price per tonne. The introduction of a protein based payment system was

only possible because of the widespread introduction of protein and moisture testing technology which facilitated the introduction of sliding scales for protein payments across all grades. A minimum protein segregation known as ASW 10 was introduced as an experiment in 1993-94. In 1995-96, ASW 10, was renamed Australian Premium White (APW) and was launched with the additional requirement for deliveries to be one of a short list of better quality hard-grained varieties. APW has now become Australia's leading export category, comprising, on average, over one third of the national crop.

The Australian wheat industry has always been concerned about the soundness of the wheat in its premium milling grades. There are very good reasons for this strategy. All Australian milling wheat is white grained and most of the current popular varieties have limited tolerance to pre-harvest rain and sprout damaged grain generally produces inferior end products.

The presence of some sprouted, or at least partially sprouted grains can be tolerated in some baked products, but this is not the case with most other wheat-based foods. Sprouted grains are undesirable in any of the premium milling wheat classes as the presence of even small quantities of the enzyme  $\alpha$ -amylase can have a deleterious effect on the colour, texture, and appearance of Asian noodles and steamed products.

All premium grades of Australian milling wheat have a short list of varieties as part of their receipt criteria. The number of varieties involved range from just 1 (in the case of special segregations for the local milling industry) to up to 30 or 40 for some of the major export grades. Generally however, the latter are dominated by 3 or 4, and rarely more than 6 popular varieties.

Australian wheat has to compete in the international market on both price and quality. Comparable competitor grades or classes of wheat for major producing and exporting countries are summarized in Table 6.

| Australia      | United States                                | Canada  | Other  |
|----------------|--|---|--|
| Prime Hard     | Hard Red Spring<br>Dark Northern<br>Spring   | Canada Western Red<br>Spring 13.5%<br>Canada Western Hard<br>White Spring                       |  |
| Hard           | Hard Red Winter<br>11.5%<br>Hard White Wheat | Canada Western Hard<br>White Spring<br>Canada Prairie Spring White<br>Canada Prairie Spring Red | Germany  |
| Premium White  | Hard Red Winter<br>10%                       | Canada Prairie Spring White<br>Canada Prairie Spring Red  | Argentina<br>Kazakhstan<br>Ukraine<br>Germany<br>China |
| Standard White | Soft Red Winter<br>Soft White Wheat          |   | Argentina<br>Kazakhstan<br>Ukraine<br>France<br>China  |
| Soft           | Western White                                |   | France   |
| Durum          | Desert Durum                                 | Canada Western Amber<br>Durum   |  |

### (c) Variety classification

Prior to the mid-1950s, Australian wheat produced in a given area was binned together, with the resultant non-descript mixture of varieties being referred to domestically, and also in the international wheat trade, as Fair Average Quality (FAQ).

The FAQ system is still in use in many wheat producing countries today. Domestic flour millers had always recognized the shortcomings of the FAQ approach so they started to purchase specific varieties with superior baking performance directly from farmers and store them separately. These varieties could then be used for blending purposes to meet specific customer requirements. This initiative was



followed by entrepreneurial grower groups, pioneered by the Prime Wheat Association based in Narrabri, NSW, which generated price premiums by producing parcels of wheat that were more attractive to both domestic millers and the Australian Wheat Board. This was the commencement of grain segregation in Australia and became the key to being able to differentiate the crop to meet the diverse needs of domestic and international buyers.

Each wheat variety released for broad-acre cultivation is classified into one of the major market categories. This is fundamental to the Australian grading system as each market category (grade) is sold in direct competition with comparable offerings from other exporters, and generate a range of price returns depending on their inherent processing characteristics, and ability to meet specific buyer's needs.

The process of assigning grades to new varieties is referred to as Variety Classification and is the prerogative of the wheat buyer. It signals to growers the commercial value that the buyer places on each variety.

#### (d) Classification in Australia

The success of grades and receival standards has been underpinned by variety classification. In Australia varieties are assessed on merit, with eligibility for inclusion in a grade based on inherent quality characteristics and suitability for specific end-uses. The classification of a variety provides market signals for growers of the potential value of that variety. This in turn helps to define quality targets for wheat breeders, and effectively determines the quality of Australian wheat that will be available for local and export purposes in the years to come. The process has been an important element of establishing and protecting the reputation and competitiveness of Australia's wheat grades.

Classification in simplistic terms is the categorization of a wheat variety into a commercial type or style of wheat based on its end-use capabilities and is achieved by referencing the quality of potential new varieties with that of established varieties.

The classification of individual wheat varieties requires an in-depth understanding of all the needs of all sectors in the wheat value chain. It demands an understanding of the fundamentals of wheat quality, wheat processing and end-product evaluation, a detailed market knowledge of products and processes, individual customer requirements and preferences, and a comprehensive awareness of the logistics of grain handling and transportation. It is a critical link between the market and the breeder.

For the major wheat grades traded in commercial circles, varieties are almost always mixed with several other varieties with differing, but complementary characteristics. Therefore

the need to be highly prescriptive for every quality parameter is greatly reduced, and a single minor defect does not necessarily inhibit a variety gaining classification.

PHOTO: C Newman



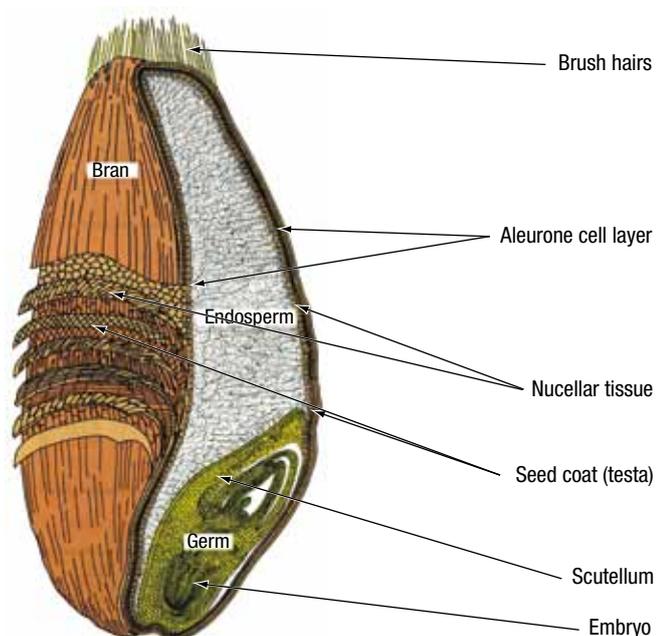
**Sampling grain at the point of delivery.**

# Wheat morphology

A knowledge of grain morphology assists in understanding aspects of grain processing and how this affects flour performance in the production of end products. Grain components like the bran layers and the crease material, while having nutritional value in human diets can have a negative impact on flour functionality in bread making. These components are the primary location of the oxidative enzyme polyphenol oxidase and if not removed effectively during milling can result in poor shelf life of fresh products like noodles and discolouration over time of stored frozen doughs. Similarly, the germ fraction which is rich in lipids, can create storage concerns if the flour is not used quickly or stored at below ambient temperatures.

The average wheat kernel (Kent, 1983) is comprised of more than 80% endosperm, 8% bran and seed coat material, 6% aleurone and between 3 and 4% embryonic tissue (scutellum and embryonic axis). Kernel size varies with production region and wheat type, with average 1,000 kernel weights for Australian Prime Hard and Canada Western Red Spring Wheat being around 30 to 35 g/1,000 kernels compared with values for EU and United Kingdom wheat varieties of greater than 48 g/1,000 kernels.

The cross section of the wheat kernel (Figure 9) shows the major groups of tissue that comprise the kernel. The seed is made up of the embryonic axis, the scutellum, endosperm, nucellus and the testa or seed coat, surrounded by the fruit coat or pericarp. The embryonic axis has root primordia and a shoot with leaf initials



**Figure 9** Cross section of the wheat kernel.

SOURCE: Wheat Foods Council, Colorado, US

and together with the scutellum comprises the embryo. The endosperm is the largest tissue of the grain and is predominantly made up of starch. Surrounding the starchy endosperm is the aleurone, a single layer of cubic-shaped thick walled cells. Aleurone cells do not contain starch but are rich in protein and lipid. The testa is only 1-2 layers of cells thick, but the pericarp is multi-layered. At maturity, the pericarp consists of dry, empty cells. Hairs (trichomes) exist at the non-embryo end of the grain, a region known as the “brush”. One of the important features of the wheat kernel compared with the generalized cereal caryopsis (Figure 2) is the presence of a crease parallel to its longitudinal axis, on the opposite side to the embryo.

The principles of flour milling involve sequential passes through roller mills and sieving to separate the bran and germ components from the endosperm, whilst reducing the endosperm material to as uniform a particle size as possible. The outer seed coat and bran layers and the crease are high in mineral material, so it is important to effect their almost complete removal when milling to a flour ash specification.

The endosperm is the functional material for making end products. Endosperm cells are packed with starch granules and remnants of protein bodies and cell membranes. During milling, the fracturing of starch granules contributes to raising the water absorption capacity of the flour for when it is mixed into a dough.

Wheat endosperm is relatively rich in protein (generally in the range 8 to 16%) and a protein gradient exists across the endosperm, being lowest in protein content in the central endosperm and highest in the outer cell layers adjacent to the single celled aleurone layer, the outer boundary of the endosperm.

The starchy endosperm is comprised of two distinct populations of starch granules. By weight, two-thirds of the starchy endosperm is occupied by large lenticular (8 to 30  $\mu\text{m}$ ) granules, the A granules, while the remaining one-third is occupied by the smaller (<8  $\mu\text{m}$ ), spherical B granules. However by granule number, 90 to 95% of total granule number is B granules and they are important functionally for water uptake during dough mixing and water retention in baked bread, slowing the “staling” process.

At the molecular level, starch granules are comprised of 2 components made up of glucose residues linked by glycosidic bonds. Long linear chains of glucose units result in amylose while a combination of linear alignment plus side-branching produces, amylopectin. Variation in the ratio of amylose to amylopectin has implications for functionality for certain wheat-based products, especially noodles, where changes in starch swelling power and gelatinization temperature are critical to producing noodles with the textural properties demanded by consumers.



# Measuring wheat physical characteristics

The physical characteristics of grain are important as they are indicative of potential processing quality. In Australia, physical characteristics are used to determine how a parcel of wheat will be segregated and stored. Measures of test weight, grain size, screenings (small, cracked and broken grains) and visual appearance, which are simple, quick and non-destructive, are routinely determined on unprocessed wheat.

## (a) Test weight

Test weight is the weight of a specific volume of grain and is an indication of the bulk density of the grain (Figure 10). It reflects the extent of grain filling and the potential for flour yield, and, is hence, an indicator of the effect seasonal conditions have had on the grain. Test weight is influenced by grain shape and packing efficiency: test weight is usually measured with a Schopper chondrometer. In Australia test weight is used to separate milling grade wheat (test weights >74 kg/hl) from feed grade wheat (test weights <74 kg/hl).

## (b) Grain size/kernel weight

Grain or kernel weight is the mass of a given number of kernels and is a useful measure of grain size. Several techniques have been developed to determine kernel weight, and the most common technique involves the counting of 1,000 grains and weighing them and then expressing the

PHOTO: Agrifood



result as the 1,000-kernel weight (TKW).

The Single Kernel Characterisation System (SKCS), as shown in Figure 10, is a recent instrumental approach to measuring the distribution of grain weight. The instrument also estimates grain hardness, kernel length and width, and calculates a softness equivalence value. Developed in North America, the SKCS system was seen as a means of differentiating between the major classes of US wheat in the marketing chain, but it is now used by flour millers to monitor the amounts of soft and hard wheat in flour mill grists.

Screenings is the amount of small, cracked or broken grains and small foreign seeds that will pass through a sieve. In Australia sieve size for wheat is 2 mm and for barley 2.2 mm. The main Australian milling grades all have maximum levels of screenings of 5%. Unmillable material includes whiteheads, chaff and light foreign seeds remaining on top of the 2 mm screen.

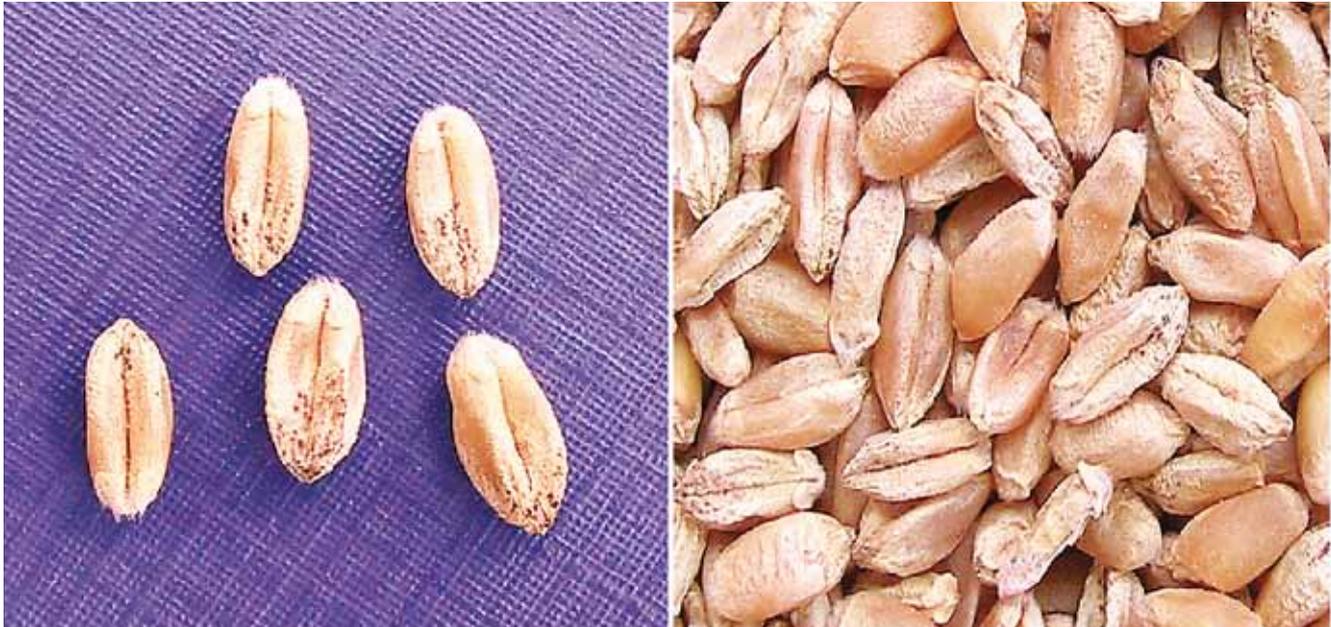
To the flour miller, screenings are the impurities in wheat removed from the grain in the wheat cleaning section of the flour mill.

Screenings differs from dockage, a term used elsewhere in the world which can also cover screenings in the Australian definition. Dockage is the levels of all impurities in a grain sample including foreign matter, weed seeds, stones, metal fragments etc, as well as small, shrivelled and broken

PHOTO: L Cato



**Figure 10** Chondrometer (left) is used to measure test weight and the Single Kernel Characterisation System (right) to measure grain weight distribution and hardness.



**Figure 11** Stripe rust affected grain showing pinched grain (left) and shrivelled kernels (right).

PHOTOS: M Shankar

wheat grain. Dockage is expressed as a percentage on a total weight basis.

High screenings levels can result from a range of sources. Plant diseases, such as the wheat rusts, attack the wheat plant during growth and the grain is unable to fully develop and mature leading to the increased production of smaller grains (Figure 11).

Frosts during the spring grain-filling period of wheat can cause both physical and visual damage. The timing and severity of low temperatures during the reproductive phase can cause grain shrivelling by impairing starch and protein deposition in the grain. Thus damage from a frost not only results in the production of small grains and high screenings, but can also have an adverse effect on grain appearance and processing quality during milling and downstream processing into wheat-based products. Frost damage can also result in grain with low Falling Number values (See point e).

### (c) Grain hardness

Grain hardness, which is largely genetically determined, may be measured by the ease with which outer layers of the grain can be removed by abrading, by the amount of energy required or noise emitted in grinding a given weight of sample, or by the amount of damage which occurs to starch granules during flour milling.

A common method of measurement is the particle size index (PSI) test. Under controlled test conditions, whole ground wheat is sifted through a 85 micron sieve and the percentage of meal that passes through the sieve is an

indication of grain hardness. Soft grained wheat will produce more fine meal than harder grained wheat, thus having a higher PSI.

### (d) Black point

Black point or black tip is a distinct dark brown to black discoloration at the germ end of otherwise normal grains. It is thought to be caused by moist and damp conditions during grain ripening. It is not related to diseases caused by fungi (Figure 12).

Many buyers perceive black point discoloration to be an indicator that the wheat is not fit for human consumption. Freedom from black point is important because it is not possible to remove all the blackened bran during milling, so some black bran particles end up in the finished flour



**Figure 12** Normal (left) and black point affected grain (right).

PHOTOS: AWB



PHOTOS: Sprouted grain AWB, falling number machine G Crosbie



**Figure 13** Sprouted grain (top) and Falling Number testing (bottom).

producing black specks in end products. Freedom from black point is particularly important in durum wheat and for wheat destined for the Middle East and Asian markets.

**(e) Falling Number**

Sound wheat is required for most food processes. Sprouting is the germination of grains in the wheat head prior to harvesting and results from rain events (Figure 13). Rain damage leads to the development of the enzyme  $\alpha$ -amylase that breaks down starch into sugars. These are needed by the developing embryo that has received signals from the rain events that it is time to start growing. Production of  $\alpha$ -amylase and other germinative enzymes negatively impacts on end-product performance of rain damaged wheat.

Objective testing of pre-harvest rain damage in Australia has been based on the Hagberg Falling Number test that measures the change in viscosity of a flour-water slurry as it goes through a heating cycle (Figure 13). A highly-viscous gel, or high Falling Number, indicates a sound wheat sample, whereas a thin slurry, or low Falling Number indicates the presence of  $\alpha$ -amylase. Evaluation of the soundness of wheat can also be assessed using the Rapid Visco Analyser (RVA) which is another type of heating cycle viscometer.

PHOTOS: Foss, DPI Victoria



**Figure 14** Protein content of grain is measured by Near Infrared Transmittance (left) and Dumas (right).

Other potential sources of  $\alpha$ -amylase in grain that has not experienced rain events after it is mature and standing in the field pre-harvest can be frost events during grain filling and the genetic defect in some varieties of late maturity  $\alpha$ -amylase (LMA). LMA results in susceptible varieties when an environmental trigger induces the production of  $\alpha$ -amylase during grain filling that remains in the harvest ripe grain.

### (f) Protein content

Protein content is a fundamental quality test of wheat used by the international wheat trade as indicating potential end-use quality. In Australia, protein content is especially important as it forms the basis for payment to farmers. The protein content of Australian wheat varies from 8 to 16%, depending on variety and environmental factors such as soil type and where the wheat is grown.

Methods for the determination of protein content include the measurement of total nitrogen by either the Kjeldahl or Dumas standard reference methods (Figure 14). Percent nitrogen analysed is converted to percent protein by the equation:

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 5.7$$

The conversion factor 5.7 is used exclusively for wheat and has been derived from the amino acid composition of

wheat protein. Other cereals and most other proteins are converted using a factor of 6.25.

Protein contents are usually expressed on a percent moisture basis, rather than on an “as is” basis. In Australia, protein contents are expressed on an 11% moisture basis, whereas in other parts of the world a 14% moisture basis is used.

At grain receival points, protein is commonly measured rapidly and non-destructively on whole grain using near-infrared reflectance/transmission (NIR/NIT) analysis (Figure 14). NIR/NIT instruments are calibrated using standard protein reference methods.

### (g) Moisture content

Moisture levels in unharvested grain gradually decrease during the ripening process. Moisture content is an important consideration at harvest as excessive moisture reduces the safe storage period of the grain and may lead to deterioration in grain quality. In Australia an upper moisture limit of 12.5% is applied at receival, and deliveries are usually in the 10.5 to 11.0% range. This is in marked contrast to northern Europe, much of the US and Canada, where moisture levels in excess of 14% are normal, and grain dryers are often required to achieve that level.

Moisture may be measured by a range of moisture meters, NIR/NIT analysis, or by standard oven drying methods.



# Flour milling

## (a) Historical development

The milling of grain to produce flour has its origins in the early history of all major civilizations and is one of the oldest known industries. The earliest milling technique was to grind the grain between 2-stone surfaces, initially akin to the use of a mortar and pestle, but later on a larger scale using saddle stones. This enabled the tough fibrous bran skin to be separated from the endosperm, which was then ground into a fine powder. Interestingly, this method of milling appears to have developed independently in a number of regions of the world.

The progression from these simple implements to rotary stone mills occurred in Europe, the Middle East, Central Asia and the Far East. The size of the mill stones increased in the Middle Ages as animal, water and wind power were used to rotate one of the stones.

White flour was first produced in Hungary and Germany in the 18th century using a number of stone mills arranged to form a series of grinding passages. Grinding severity was adjusted so that the grain was broken down progressively, enhancing the separation of the bran from the endosperm. Purifiers, which are long rectangular machines with oscillating sieves through which a current of air is drawn, were introduced to remove bran from intermediate stocks. The remaining material high in endosperm content was ground into white flour on additional stone mills.

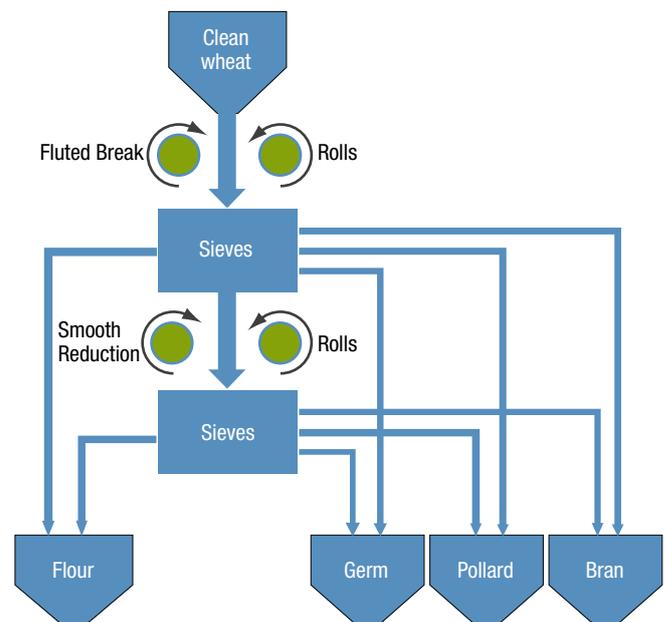
Modern flour mills have replaced millstones with steel rollers (roller milling) and use modern design plansifters and new ancillary machines. Modern milling still has the same aims of gradual size reduction to produce flour with as uniform a particle size distribution as possible. The flow diagrams of flour mills in all countries have been made progressively less complex over the past 50 years, with the exception of the Japanese flour milling industry, which produces exceptionally white flour of very low ash content.

## (b) Milling

Traditionally, milling has involved repetitive grinding and separating in a gradual reduction system to separate the different botanical components of grain (seed coat, endosperm and embryo) to produce flour of as uniform particle size as possible. More recently, pearling and the use of Peritec systems in semolina mills have become popular. These new systems remove the outer seed coat and aleurone layers and so facilitate the production of very low ash content flours.

When trying to assess the milling quality of any wheat there are two major factors relating to the structure of the grain that are important.

1. The potential yield of flour from the grain depends on how much endosperm is present relative to the amount of seed coat (bran) and embryo (germ).
2. The ease with which endosperm is separated from the bran and germ and reduced to flour.



**Figure 15** Flow diagram of a typical commercial flour mill.

SOURCE: Modified from [www.nabim.org.uk/flourproduction.asp](http://www.nabim.org.uk/flourproduction.asp)

## (c) Milling yield

Milling yield is a measure of the quantity of flour that can be produced under a given set of milling conditions.

## (d) Wheat cleaning

Wheat delivered from farms to flour mills may contain impurities such as foreign seeds, dust and stones. To prepare wheat for milling the impurities need to be removed by separating the wheat from the heavier impurities and the lighter dust.

Removal techniques include scouring, brushing and aspiration as the impurities differ from wheat in size, specific gravity, shape, texture and air resistance.

## (e) Conditioning (tempering)

Conditioning is the process where water is added to wheat prior to milling. The amount of water added depends on the initial moisture content of the grain and the type of wheat being milled. Typically wheat is conditioned to a moisture level of between 14 and 16% and then allowed to lie in conditioning bins for between 10 and 20 hours. During conditioning the bran layers are toughened, minimising

shattering during milling and making the endosperm more friable (crumbly) and requiring less power to be ground into flour.

With modern milling practice, where the emphasis is on achieving high flour extraction rates, the role of conditioning assumes even greater importance. To maintain satisfactory flour colour and ash levels while achieving an almost complete separation of bran from endosperm, it is paramount that the wheat be conditioned correctly to its optimum state for milling. Soft-grained wheat requires a shorter conditioning time and less water addition than hard-grained wheat to achieve optimum milling results.

#### (f) Commercial milling

In roller milling, the conditioned wheat is fed into 2 steel cylindrical rolls separated by a small adjustable gap (Figure 15). The rolls, which have longitudinal grooves rotating at different speeds, grip the bran tearing it away from the endosperm and break the endosperm into granular chunks (semolina) or fine powder (flour).

Plan sifters grade the ground material into bran, coarse and fine fragments and flour, according to particle size. Larger bran fragments are subjected to a further 3 or 4 break roll-sifter passages, until all of the endosperm is removed.

The break system fractures wheat grains releasing semolina particles and leaving the bran in the largest particle sizes as possible thus minimising bran contamination in the semolina. Some flour is produced at this time but the main production of fine flour comes from the later reduction stages. It is common in commercial flour mills to have up to 6 break rolls in the mill flow.

The particles of purified semolina are then crushed to fine flour by the “reduction” system. This is comprised of roller mills fitted with smooth rolls operating at slightly different speeds. Flour is removed by sifting the ground stock over fine mesh nylon screens. Coarse mesh sieves separate the bran flakes. The size of any intermediate product is gradually reduced by subjecting it to repeated roll and sifting treatments. Up to 8 to 12 passages may be employed depending on the design of the plant.

Stock failing to pass through the flour sieves at the completion of the reduction system becomes offal (pollard), as does the coarse material (bran) rejected at the termination of the break system.

All the mill products, including flour, wheat germ and bran are either bagged or stored in bulk bins. Flour is normally stored for at least 3 days before being delivered to bakeries and food processing factories as the ageing process has a beneficial effect on the flour for most purposes.

#### (g) Laboratory milling

Laboratory milling, sometimes referred to as test milling, is used to prepare as reproducibly as possible flours from small quantities of grain for assessment of milling yield. Those flours are subsequently used for analytical, dough quality, and end-use evaluations. Test milling is routinely used by commercial flour mills for wheat intake quality control and by wheat breeding programs as part of breeding for improved wheat quality.

In most Australian cereal laboratories the Bühler model MLU-202 experimental mill (Figure 16) is used for small-scale milling assessments. The experimental mill has reduced break and reduction systems, limited to 3 rolls each with limited ability to adjust only 2 of the 3 roll gaps. Nevertheless, properly set up, these mills can produce flour yield estimates highly correlated with commercial extractions and flours that give dough and end-product test results predictive of performance in commerce.

Breeding programs, which assess large numbers of samples, often use even simpler designed Quadrumat mills with just 4 rolls (2 break and 2 reduction, with no capacity for



Figure 16 Bühler laboratory mill.

PHOTO: Agrifood



adjustment) which provide a basic indication of milling potential and a sample of flour that can be used for subsequent testing to aid in their selection of potential wheat varieties.

### (h) Flour appearance

Flour appearance can be divided into 2 components – the purity of the flour and flour colour. Measurement of flour appearance is achieved in several different ways, such as flour ash, Kent Jones colour grade, and with the use of tristimulus colour meters. Contamination of flour from ash and bran particles dulls the appearance of the flour.

Ash is the term used to describe the mineral content of grain or flour and is concentrated in the outer layers of each kernel. The ash levels of wheat (on a weight basis) generally do not exceed 1.6% and in Australian commercial flour mills, flour ash levels are generally around 0.65%. The determination of ash involves incinerating a sample and weighing the resultant mass. In addition to dulling flour appearance, bran particles and excessive levels of ash, can lead to discolouration of, and speckiness in end products. The acceptability of such contamination varies with each end product.

Another assessment of flour purity, widely used in Australia, has been the Kent Jones test, which is a reflectance measurement taken on a flour-water slurry (Figure 17). Kent Jones values are indicative of flour brightness and bran contamination.

More recent approaches to measuring flour purity have been with the use of instruments such as Tristimulus colormeters and Fluoroscan®. Tristimulus colour instruments (Figure 17) use the definitions of colour published by the Commission Internationale de l'Eclairage that describes colour using colour space parameters. ( $L^*$  is the measure of the degree of whiteness on a scale from 0 to 100, where pure white is 100 and black is 0.  $a^*$  is the measure of redness and greenness on a scale from +60 to -60, where red is positive and green is negative, and  $b^*$  is the measure of yellowness and blueness where yellow is positive and blue is negative). Tristimulus colormeter instruments have gained widespread acceptance for their objective measurement of flour and end-product colour.

Flour users know that whiteness or yellowness is a key point of differentiation between good and bad quality flour. The general preference is for white and bright flour because it is more versatile across a range of end products. However, for a product like Japanese Udon noodles, the market preference is for noodles made from creamy coloured flour.

The Fluoroscan® instrument was developed to discriminate between good and bad milling performance. It can be placed directly into a flour milling system and can quickly and consistently provide direct measurements of flour ash and aleurone and pericarp specks by image analysis.

PHOTOS: Colour meter – D Miskelly, Colour grader – Agrifood



**Figure 17** Tristimulus colour meter (top) and Kent Jones flour colour grader (below).

# Wheat flour dough

Wheat flour is unique in its ability to form viscoelastic dough when mixed with water. The properties of dough are largely due to interactions between hydrated gluten proteins.

Dough properties are largely determined by variations in protein content and protein quality, which, in turn, are dependent upon the wheat varieties selected to be milled into the flour.

Protein content and dough properties are, therefore, important in the manufacture of most wheat-based foods. For example, in bread dough, hydrated gluten when mixed forms a continuous elastic network which allows retention of air and gases formed during the fermentation stage, thus providing structure to the loaf during the baking phase.

## (a) Dough properties

In order to assess the functionality of wheat flour in dough, it is necessary first to be able to measure the quantity of water needed to make a standard dough and the energy taken by the mixer to make the dough.

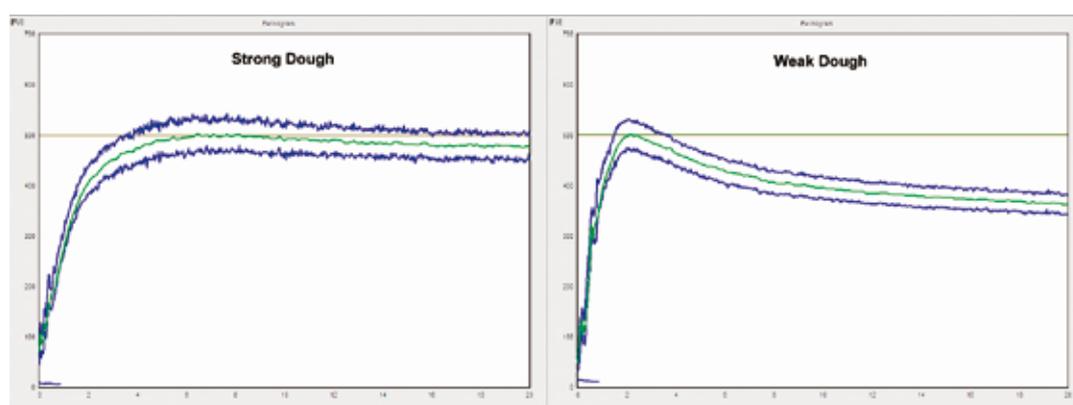
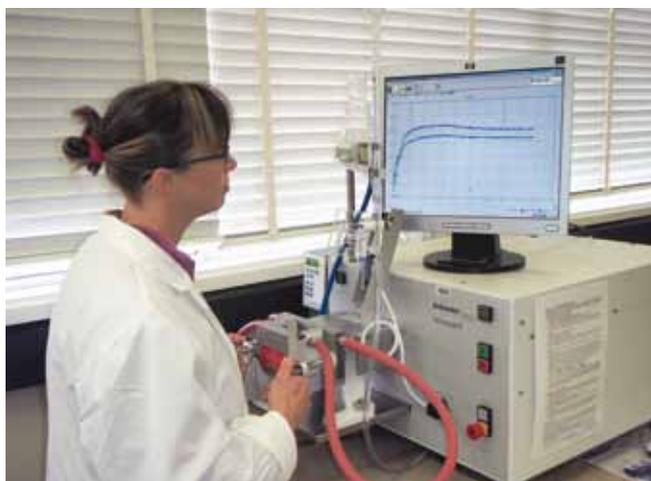
Once the dough is formed, assessment of its strength,

elastic and viscous properties can give a good indication of its suitability for use in end products.

## (b) Measuring dough properties

The two most common laboratory scale recording dough mixers are the Brabender Farinograph (mixing done with blades, Figure 18) and the Mixograph (mixing done with pins). Both record the resistance forces encountered by the mixing blades or pins as they mix dough. Interpretation of the Farinograph mixing curve gives a measure of dough strength, stability, mixing time and flour water absorption as the amount of water required to develop the dough to a standard consistency. The Mixograph can be operated using either (a) standardized water absorption levels set separately by hard versus soft wheat, or (b) based on protein content. Also included are time to peak development (mix time), band width at peak development, breakdown from peak development after 5 or 10 minutes (alternative indications of stability and dough breakdown), and bandwidth at breakdown (indicative of tolerance to mixing).

PHOTOS: DPI Victoria



**Figure 18** The Farinograph and the mixing profiles of a strong and a weak dough.



Many laboratories also use the Brabender Extensograph (Figure 19) to further determine dough properties. The Extensograph is a recording dough stretcher used to assess dough pieces mixed to a standard dough consistency in the Farinograph. The mixed dough is formed into a cylindrical shape and the instrument stretches the dough piece until it breaks. The instrument measures the force required to extend the dough cylinder at a fixed rate of extension and measures dough strength (resistance to extension) and dough extensibility.



The Brabender instruments use larger quantities of flour (50 or 300g) than the mixograph (generally 10 or 20g). Consequently, for early generation assessment of dough properties in breeding programs the mixograph is the preferred instrument while in later stage evaluations, where sample size is less of an issue, Brabender instruments are used.

Both Brabender instruments and the Mixograph are accepted internationally by cereal chemists, flour millers, processors and breeders. The recently developed Newport DoughLab measures dough mixing under standard and high-energy mixing conditions and is able to operate under adjustable temperature conditions. Standard methods of analysis are published in the methods books of RACI Cereal Chemistry Division, AACC International and ICC.

The French-developed Chopin Alveograph is popular in France, China and parts of Africa. This instrument measures the resistance to deformation and extensibility of a clamped disc-shaped piece of dough by forming a bubble using air pressure applied from below the dough piece.

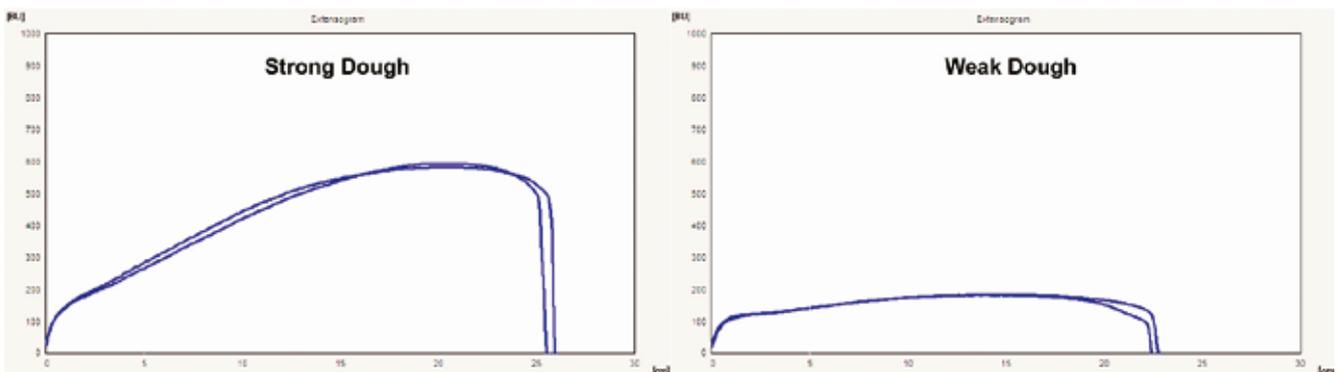
A common feature of all these rheological tests is that they are used to predict the suitability of flours for use in end products

### (c) Interpretation of dough properties

Dough strength can vary from very strong through medium to weak. In all cases, these differences can be readily observed in the mixing curves of the Mixograph and Farinograph (Figure 18) or the traces produced by the Extensograph and Alveograph.

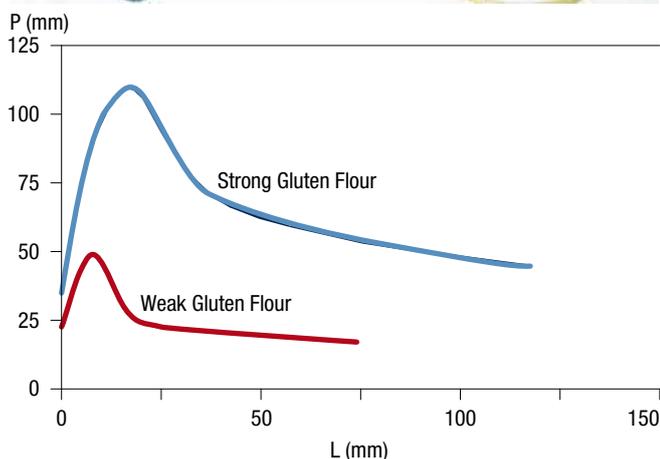
Dough handling properties are determined from the Extensogram and can be described as stable, well balanced, extensible or weak. Well balanced dough is characterized by having dough strength combined with a good level of extensibility. Over strong or over stable flours may be described as tough or bucky and have relatively high resistance to stretching and somewhat shorter extensibility.

Most end products made from wheat flour require



**Figure 19** Partial view of the extensograph and curves of a strong and weak dough.

PHOTOS: DPI Victoria



**Figure 20** Alveograph (top) and typical graphs of a strong and a weak flour.

SOURCE: T Westcott and T Watts

balanced dough properties. End products needing a sheeting procedure in their manufacture, such as noodles, flatbreads and some biscuits, require flours with good extensibility.

Extensibility is a measure of how far a dough piece will stretch before breaking and is determined as the distance (cm) from the commencement of stretching until the breaking point and the trace reverts to the baseline of the chart recorder. The maximum resistance is the maximum height of the curve (Figure 19).

Extensograph curves can be easily used to distinguish between weak, strong and over-strong dough. Considered together, extensibility and maximum resistance, provide an insight into whether any dough has the optimum balance of strength and extensibility needed for most end products.

Alveographs produce alveograms where the length (L) of the trace (mm) indicates dough extensibility, and the deformation energy (W value) and the overpressure (P) required to expand the dough disc, are measures of the strength of the flour (Figure 20). Information on the balance of strength and extensibility is provided by the P/L ratio.

#### (d) Water absorption

Flour water absorption is one of the most important flour quality parameters to end-product manufacturers, as it has a significant effect on the yield of finished products. Water absorption is influenced by the protein content of the flour, the proportion of starch granules damaged during milling and the quantity of non-starch polysaccharides (cell wall material, mainly pentosans).

Protein content is a major contributor to flour water absorption as wheat protein absorbs around 2 to 3 times its weight in water during the dough making process. The quantity of damaged starch in a flour depends on the hardness of the original grain, the way that it has been conditioned (water added) prior to milling, and the way that the wheat has been milled. By controlling starch damage, commercial millers endeavour to standardize the water absorption capacity of their flours in order to provide an optimum and consistent bakery absorption for their customers. Damaged starch absorbs approximately 3 times its own weight of water.

Pentosans are also a significant contributor to flour water absorption capable of absorbing 12 to 13 times their own weight of water. However, as they are only present in relatively small (<3%) quantities and are difficult to measure, they are often overlooked. Varieties vary not only in the thickness and composition of their cell walls, but also in the ease of separation of them from the endosperm in the mill, providing a potential explanation for apparent anomalies in flour water absorption values.

#### (e) The relationship between grain hardness, water absorption and dough properties

The market generally prefers hard-grained wheat with high, but not excessive, water absorption levels. This combination is also usually associated with longer dough development and dough stability times and these wheats are used in a diverse range of bread making technologies. By contrast, soft-grained wheat is associated with low water absorption levels and short development times making them more suited to cake and biscuit making.

The actual capacity of flour to absorb water is influenced by the combined effects of protein content, grain hardness, and the degree to which starch granules are damaged during the milling process and the amount of non-starch polysaccharides, mostly pentosans in the flour.

#### (f) Starch

Starch is the major component of wheat, being 53 to 62% of the grain and 62 to 71% of flour. Starch is composed of amylose and amylopectin. Amylose is a linear polymer



of glucose subunits, whereas amylopectin is a branched polymer of glucose subunits.

Since the late 1970s, attention has been focused on quality variation in the starch component of flour and this has been



**Figure 21** The Rapid Visco Analyser is used for measuring pasting properties of flour and starch. PHOTO: Newport

found to be of significance in certain products, particularly noodles. Critical factors influencing the functional properties of the starch include the ratio of the key starch components amylose and amylopectin. The amylose content of most wheat is between 25 and 30%, but in wheat preferred for Japanese udon noodles, the amylose content is closer to 20%.

Starch granules can be mechanically damaged during the milling process and, this in turn, increases the water absorption of the flour and influences fermentation time during baking.

Starch degradation caused by the enzyme  $\alpha$ -amylase, resulting from either rain damage prior to harvest or from the development of Late Maturity Alpha Amylase also has a major influence on the suitability of wheat for production of end products.

Starch quality can be measured in a number of ways, including the swelling properties of the starch or the pasting properties of the starch or flour slurries when heated. When starch is heated in excess water, the granules swell and a paste is formed as the starch gelatinizes. The relative viscosity of the paste is measured using recording instruments such as the Brabender Viscograph or the Rapid Visco Analyser (Figure 21).

Starch gelatinisation is important in baking as it assists in forming and stabilising the loaf crumb structure. It is also implicated in staling of baked goods. Starch swelling properties influence the appearance and textural properties of noodles, particularly white salted noodles, but are also important in other products such as batters.

# End products

The majority of the quality measurements previously described are predictive measures of end product quality. The critical and ultimate test of the suitability of a wheat for any end product is to manufacture the end product, using either full scale or laboratory scale test methods.

Establishing links between various quality measurements and measured end product traits is challenging, time consuming and usually requires a fairly large sample of material for testing. Therefore, considerable quality research has focused on predicting end product performance using dough rheological measurements and small-scale laboratory tests.

Wheat breeding programs generally only have small quantities of grain available for testing and large numbers of breeding lines to evaluate, so have a suite of small-scale, rapid and predictive tests that they use. Flour mills require rapid tests to monitor the quality of wheat being utilized in their wheat grists, so use rapid, small-scale tests supported by end product tests to predict flour performance.

Wheat-based foods for human consumption can be categorized into 6 broad groups (Table 7).

**Table 7 Major wheat flour end-product groups.**

| Breads                        | Noodles         | Asian dumplings                    | Biscuits    | Cakes           | Durum products |
|-------------------------------|-----------------|------------------------------------|-------------|-----------------|----------------|
| Pan breads                    | Yellow alkaline | Chinese dumplings (Jiaozi, Guotie) | Crackers    | Sponge hi-ratio | Pasta          |
| Hearth breads                 | White salted    |                                    | Hard sweets | Madeira         | Couscous       |
| Middle Eastern flatbreads     | Instant         |                                    | Cookies     | Fruit cakes     |                |
| Indian flatbreads             |                 |                                    | Wafers      |                 |                |
| Asian steamed breads and buns |                 |                                    |             |                 |                |
| Tortillas                     |                 |                                    |             |                 |                |

## A. Breads

Bread is one of the most common staple foods prepared from wheat flour. Different countries and cultures have their unique varieties and preferred styles of bread, but common to all the bread types is the preparation of dough with flour, water and other additives such as salt and yeast. A range of bread types is shown in Figures 22 and 23.

Breads can be flavoured by the inclusion of herbs and seeds. Chinese steamed breads enclosing a stuffing are termed buns or bao and may contain meat, vegetables or sugar-based fillings.

Despite the differences in the final product, there are 4 basic processing steps in the production of bread.

### (a) The 4 basic bread processing steps

#### (i) Mixing

Dough formation first requires the mixing of the dry ingredients prior to the addition of water or all the liquids and then mixing or kneading to develop the gluten to produce a cohesive dough. Traditionally this mixing and kneading was achieved by hand but most bakeries now use mechanical mixers. Commercial mixers vary widely in capacity and mixing intensity.

#### (ii) Fermentation

After mixing, the dough is allowed to rest with the aim of allowing the microorganisms (yeasts or bacteria) in the dough to grow. The microorganisms use the sugars and some of the carbohydrates as their food substrates and enzymes, carbon dioxide, alcohol, and flavour components are produced. The carbon dioxide increases the dough volume and the dough undergoes further development and mellowing. The gas retained by the dough influences the crumb structure that will exist after baking. Fermentation time varies depending on the type of mixer and ingredients in the formulation, level of yeast addition, dough temperature and moisture.

#### (iii) Proofing

The fermented dough is divided and moulded to provide enough dough for each individual loaf. The dough pieces are then rested (the final proof) to allow the dough to relax and for the yeast to produce more carbon dioxide until the desired loaf volume and texture is achieved.

#### (iv) Baking

Breads may be cooked (baked) using heated air, direct contact with a hot surface or steam.

### (b) Major bread types and processing methods

#### (i) Pan breads

Pan bread is the term used to describe loaf bread, either sandwich or open top, produced in a conventional baking tin or pan. Pan breads are produced commercially using a number of different methods.

##### (1) The straight dough method

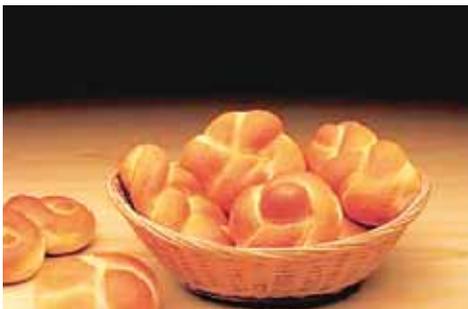
In this method, the dough is produced by mechanical kneading and then allowed to ferment for between 2 and 6 hours, but sometimes longer, during which time further dough development



PHOTOS:AWB



**Figure 22** Different bread types 1 (clockwise from top left), pan bread high top, pan bread flat top (baked with a lid on the tin), hearth bread and Philippine Pandesal (bread with salt).



**Figure 23** Different bread types 2 (clockwise from top left), baguette, focaccia, plait, bread rolls.

occurs. The dough is then divided and processed. Fermentation time required to mature the dough depends on flour quality, dough temperature and yeast content. It is a common practice to release some of the gas generated half way through the bulk fermentation period by “knocking” (kneading or punching) the dough. Dough is then divided, oulded and deposited directly into baking pans for proofing and baking.

The straight dough method of bread making using bulk fermentation, is still widely used in small bakeries. No special

mixer is required. Mixing can continue for up to 30 minutes until a smooth dough is formed.

**(2) The rapid dough method**

In the rapid dough bread making process, low, medium or high intensity mixers are used to fully develop the dough, eliminating the need for bulk fermentation that occurs in the straight dough process. Rapid dough development is obtained through the addition of gluten modifying and softening agents, at the commencement of mixing.

The rapid dough process enables bread to be made in 2 hours, using medium strength and medium protein content flour. Because specialized equipment is not needed, the method is suitable for small bakeries. While formulations may vary slightly for most ingredients, there is a significant difference in the sugar level used in this style of bread produced in Australia and in many Asian countries. In Asia, sugar levels as high as 25% may be used, necessitating other changes to the formulation such as higher flour protein content, yeast type and levels, salt and modifiers.

**(3) The sponge and dough method**

This method is popular in North America and Asia. Part of the flour is mixed with the yeast and the other ingredients to produce a slurry which is allowed to ferment for between 90 minutes and 3 hours. The resultant product, the sponge, is then mixed with the remaining flour and allowed to ferment for a varying period of time before being moulded and tinned for final proofing before baking.

The sponge and dough method produces bread with



**Figure 24** Arabic flatbreads as they emerge from the oven and (right) as packed.

PHOTOS: AWB, T Westcott

a very fine, uniform cake-like crumb structure. The baked bread has good aroma and flavour. The method is suited to the sweet palates of North Americans and Asians with the sweetness achieved through the use of high sugar additions.

#### (ii) Hearth breads

Hearth breads are baked by placing the fermented dough piece directly on the bottom or hearth of the oven, rather than in a tin as in the case of pan breads (Figure 22). This method of breadmaking is the most common method of bread production worldwide, and is still extensively used in small bakeries in Australia. Bread made by this method should have a distinctive taste and aroma with an open coarse texture. Keeping quality is not considered important since it is usually consumed on the day of baking.

#### (iii) Flatbreads

There are a wide variety of flatbreads and they are a staple food in some Middle Eastern and North African countries, Central and South America and the Indian Sub-continent. The basic formula is flour, water and salt. Dough may be produced using yeast, or natural sours (a culture retained from previous day's production) or may be unleavened.

In the Middle East, flatbreads are the predominant bread type. Thin and flat dough pieces are baked quickly at a very high temperature. In India, flatbreads are often baked on a hot metal plate or deep fried in oil. Some flatbreads throughout Asia and the Middle East are baked in clay pot ovens (tandoors). In some countries, fuel is in short supply and alternative cooking means may be employed. In China steam is a common means of cooking bread although the pieces are generally small, about the size of a bread roll.

#### (1) Arabic flatbread

Arabic flatbreads (Figure 24) form two layers during baking (pocketing) unless the dough piece is docked (pricked) before baking. The dough is usually produced by the straight dough method, with variable fermentation and proof times. The flattened pieces of dough are proofed for a period under controlled humidity conditions, which allows slight surface dryness. Adequate proofing is crucial to good pocketing.

Baking temperatures are very high, from 400 to 600°C. At this temperature steam is generated inside the dough within a few seconds, inflating the dough and producing the

characteristic hollow space or pocket. Baking time depends on the type of product. Some flatbreads are baked at 400°C for 90 seconds, others only 15 seconds at 600°C.

Arabic bread stales rapidly so is generally eaten within hours of being baked. Typically it is eaten with filling, rolled to encapsulate the filling or the hollow pocket may be filled. Consumers demand that the breads are easily rolled and do not tear or crack. Visual appearance is important with even surface colour, few blisters and even internal texture.

#### (2) Iranian flatbread

There are several types of Iranian flatbreads, including barbari, lavash, sangak and tanour. These breads are made by similar processes to Arabic breads and are generally leavened.

Dough is prepared from a simple formula of flour, water, salt, yeast and sometimes baking soda. After a variable fermentation period, the dough is divided before moulding and sheeting. Before baking, barbari is proofed for up to 20 minutes, while lavash dough may be proofed for less than 2 minutes.

The breads are docked before baking to avoid pocketing and are baked in hot ovens at 220 to 380°C for 1 to 5 minutes. The bread has a short shelf life and is eaten within hours of being produced.

#### (3) Indian-style bread

Examples of Indian breads are given in (Figure 25). Leavened bread cooked in a tandoor is called naan. These breads are typically consumed in Northern India. The leaven and the naan vary greatly from region to region. Naan are made from wheat flour and a leavening agent. The leaven can be yeast, a sourdough or be chemically leavened with self raising flour and sodium bicarbonate.

Chapatis are unleavened flatbreads consumed over most of the Indian Sub-continent. They are a staple food of Southern and Central India and can be served at every meal. Chapatis are traditionally made from finely-ground wholemeal flour (atta) and water. The dough is mixed, kneaded and rested for a short time and then rolled to about 20 to 25 cm diameter and 3 or 4 mm thick. The pieces are cooked on a hot griddle. Fresh chapatis should be soft, smooth and pliable and have a creamy appearance. They must tear easily and smoothly and should not turn leathery or brittle before use.

Parathas are made from chapati dough rolled to about



PHOTOS: T Westcott



**Figure 25** Indian breads (clockwise from lower left) parathas, roti, chapati and naan.

20 to 25 cm diameter and 3 or 4 mm thick. Ghee (clarified butter) is spread on the top surface before the dough is folded in half. More ghee is spread on the dough and it folded into either halves or thirds. The dough is then moulded into a ball and finally rolled out to 20 to 25 cm and then cooked on a hot griddle. Parathas have a crisp and flaky texture somewhat akin to Western style puff pastry and may be eaten plain or stuffed with other food.

Puris are essentially deep fried chapati. Flour water absorption is an important requirement to ensure sufficient moisture in the dough piece to guarantee sufficient puffing during cooking. Grain hardness is also an important requirement to ensure the cooked dough piece is neither brittle nor leathery.

#### (iv) Tortillas

Tortillas (Figure 26) are a round, soft, white, flexible, single layered flatbread originating from Central and South

PHOTOS: T Westcott



**Figure 26** Tortillas.

America. Wheat-based tortillas are popular throughout the world and in Australia are commonly used as a wrap in fast food outlets.

Commercially-manufactured tortillas are produced either with a hot press or sheeting rolls. The hot press is the most popular method. The major ingredients include flour, water, shortening, salt and baking powder, which are mixed to combine and form the dough. After mixing, the dough is either divided to form a ball prior to the hot press, or sheeted and die cut. Formed dough pieces are baked in a traveling oven at 190 to 300°C for 17 to 40 sec which reproduces the appearance of baking on a hot plate.

In Mexico wheat tortillas are typically eaten freshly baked. In the US they are often stored in long life packs where the food service agent or consumer heats the product just prior to consumption. This softens the bread so that it is flexible enough to be wrapped around loose, moist foods such as meat and salad.

#### (v) Steamed breads and buns

Steamed bread is a popular food in most parts of Asia and is a staple food in Northern China. Steamed breads may be prepared plain (mantou) or as buns (bao) stuffed with a savoury or sweet filling. Regional preferences exist as to product type and eating quality (Figure 27).

##### (1) Northern style (mantou)

Flour for mantou is milled from moderately hard grained wheat. Ingredients typically consist of flour and water (40 to 45%). Low speed mixing is used for dough preparation and the fermentation is either by a yeasted dough or by a sour

PHOTOS: T Westcott



**Figure 27 Steamed bread and buns.**

dough. The sour dough is neutralized with alkali and remixed with additional flour prior to moulding, proofing and steaming for about 20 minutes.

Northern style steamed bread should have a dense texture and a chewy, elastic and very cohesive eating quality. The surface should be white, smooth and free of blemishes.

### (2) Southern-style steamed bread and steamed buns

Southern-style steamed bread and steamed buns are popular in all of China and most parts of SE Asia. Both the bread and the buns have a similar texture and wheat quality requirement.

Ingredients for these products consist of flour and water, with the addition of salt, fat and high levels of sugar. Leavening of the dough is achieved by yeast or sour ferments, with or without the addition of chemical leavening agents. The dough is divided, moulded and proofed prior to steaming for about 20 minutes.

Steamed buns (*bao zi*) may be savoury or sweet and contain fillings such as meat, vegetables or sweet red bean paste.

Southern-style steamed bread and steamed buns have an open texture and soft, elastic and cohesive eating quality. The surface should be white, smooth and free of blemishes.

Flours for steamed breads and buns are produced from soft grained wheat of relatively low protein content and low-to-medium dough strength.

While industrially produced steamed breads are typically cylindrical in shape, cooked steamed buns are more spherical. The internal texture and structure varies according to regional preferences and formulations differ to satisfy regional preferences.

## B. Noodles

Wheat-based noodles are a traditional food widely consumed throughout Asia. Noodles were typically made in the home for household consumption but are now widely available commercially and depending on the region and type, may be purchased fresh, cooked, long-life processed or dried.

There are a number of noodle types and regional preferences exist as to product type, preference and quality. Preferences may include noodle shape (thickness and width), length and texture. Flour protein content, added starches and gums and wheat variety have an influence on texture, resulting in a range of noodles that may be variously described as soft, chewy, slippery or firm.

Freshly-processed uncooked (raw) noodles must be consumed within 1 or 2 days as they typically have a high moisture content and so a limited shelf life. Raw noodles may be chilled or further processed by boiling, steaming, frying or drying to delay spoilage.

Boiled or steamed noodles, depending on the temperature of storage, must be consumed within 2 or 3 days. Steamed noodles that have later been dried or fried have a much lower moisture content and hence a longer shelf life. A long-life process is also used where fresh noodles, with a relatively low pH, are sealed and then pasteurized in the bag. Such noodles, depending on storage temperature may have a shelf life of several months.

Noodles can also be dried to produce a shelf stable product.

### (a) White-salted noodles

White-salted noodles are made by mixing flour, water and salt into a dry, crumbly dough. The noodle strands are formed either by hand rolling and cutting, or commercially by passing the dough through a number of sheeting rolls until a dough sheet of the desired thickness is produced. The noodles are then passed through a set of cutting rolls to produce noodle strands of the desired width.

Dried white-salted noodles, prepared by slowly drying raw noodles, are the most popular type manufactured in China and in many parts of Asia. A major quality consideration is the whiteness of the noodle strands. The Chinese market is less discriminating for flour quality attributes. A moderately-hard wheat is normally used, producing a white noodle with a firm elastic texture.

### (b) Udon

Udon (Figure 28) are a type of white salted noodle popular in Japan. Essential noodle quality parameters include brightness, freedom from specks, colour and colour stability and the texture and mouth-feel of the cooked noodle. Japanese udon should be soft and elastic with a smooth

PHOTOS: AWB, G Crosbie, T Westcott



**Figure 28** Noodles varieties of instant, udon, and Hokkien.

surface and creamy colour. Consistency in these quality factors is also of paramount importance. Flours for udon noodles are traditionally milled from soft grained wheat to low extraction rates (typically 50% to 60%) to meet the low ash and bright colour requirements demanded by processors and consumers.

### (c) Yellow alkaline noodles

Yellow alkaline noodles are made from flour, water, salt and an alkaline salt solution (*kan sui*) mixed to form a dry, crumbly dough which is then sheeted with rolls to form a dough sheet. Other additives, such as wheat gluten, starches, gums, antioxidants, egg, yellow colouring and oil may also be used.

The yellow colour of these noodles is formed by reaction of the added alkaline salts with natural compounds occurring in the flour. A type of yellow alkaline noodles, Hokkien noodles, is shown in Figure 28.

Yellow alkaline noodles have a unique flavour and texture imparted by the addition of the alkaline salts. Noodles are required to be bright, glossy and free from specks and have a firm and elastic texture.

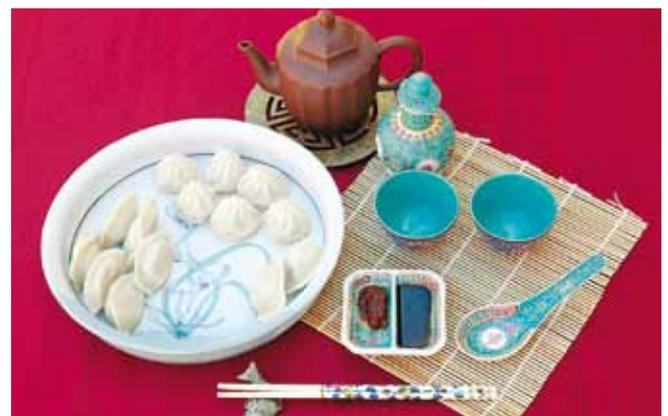
### (d) Instant noodles

An important class of alkaline noodles is the instant noodle (Figure 28). These are increasingly popular as a quick, cheap convenience food both in Asia and also in Australia.

Starches are often added to instant noodle dough to produce a chewier noodle texture. Alkali levels in instant noodles are typically lower than for other yellow alkaline noodle types.

The main ingredients typically consist of flour, water, salt and an alkaline salt solution. Other additives, such as gums, antioxidants, colourings, starches and gluten, are also added to allow faster cooking and to modify the noodle texture.

Instant noodle manufacturing is usually highly mechanized.



**Figure 29** Asian dumplings.

PHOTO: T Westcott

After sheeting and cutting, the cut noodle strands are either steamed and then fried, or steamed and then dried.

Instant noodles are usually eaten as a quick snack in a broth and single serve packets of instant noodles usually include a flavour sachet of soup and/or other condiments in the package. Most instant noodles of this type are steamed and fried. These meals come in bowl and packet packaging forms. They are simply prepared by adding boiling water to the bowl or the packet contents to boiling water. Cooking times are quite short (just a few minutes) after adding the boiling water. The noodles should have a firm and elastic texture.

## C. Asian dumplings

Dumplings (*jiaozi*) are a popular food in most parts of Asia (Figure 29). There are many different ingredients that can be incorporated in the filling, including minced pork, prawn and various vegetables. Mixtures of these fillings are popular with consumers. The filling is placed into the centre of the wrap, which is then carefully folded around the filling. Folding techniques and hence dumpling shape and size vary with



**Figure 30** Assortment of biscuits.

region, cooking method and product type. The dumplings are cooked either by boiling, steaming or frying.

Flour for Asian dumplings can be milled from soft or hard wheat. The dumpling wrap is produced by mixing flour and water (and sometimes salt) into a workable dough followed by rolling (sometimes by hand) or sheeting the dough to the desired size and thickness.

Asian dumplings, in general, are required to be a bright, white colour. The boiled and the steamed cooked dumplings should have a soft, smooth and elastic mouth feel. The partly fried dumplings (potstickers) should have a bright, white top colour and the bottom should be crisp and golden. The dough should remain intact during and after cooking.

## D. Biscuits

Biscuits are produced from flour and/or starch, fats (shortening) and other food ingredients. Biscuit flour may be milled from soft or hard wheat or a mixture of soft and hard wheat. The protein content of biscuit flour may range from 7.5% to 12.5%.

Biscuits containing mainly flour and water – with quite low additions of sugar and shortening – are referred to as crackers. Sweet biscuits usually contain higher levels of sugar and shortenings, and, therefore, lower quantities of flour.

There are a number of sweet biscuit types, including, semi-sweet, hard-sweet, cookies, shortbreads, plain biscuits and wafers, differing principally in the amount of flour, sugar and fat used and the type and amount of other added food ingredients.

Each product type has differing requirements for processing techniques and flour properties. Some of the product types are shown in Figure 30.

As most biscuits are sold as dry products, they are required to be low in moisture. Consumer preference is also for well-defined shape and size, uniform density, appearance and texture (product specific).



**Figure 31** An assortment of cakes.

PHOTOS: T Westcott

## E. Cakes

Cakes (Figure 31) are typically produced from flour, sugar, eggs and shortening, including emulsifiers, as well as other food ingredients. Cake flours may be milled from both hard and soft wheat and these flours may be modified through chlorination or heat treatment.

Sponge or hi-ratio cakes, which have a very light and soft texture, are usually made from stream flours of very small particle size from both hard and soft wheat. Hi-Ratio flours, capable of holding high levels of sugar and egg are typically chlorinated or heat treated.

Madeira or pound cakes are quite dense in texture and contain significantly lower levels of sugar and egg relative to the flour weight. Flours used can also be milled from both hard and soft wheat and again may be chlorinated or heat treated.

Fruit cake is a heavy cake laden with dried fruits and nuts. It is common practice to use flours with stronger gluten properties, such as a medium bakers flour, in order to support the fruit in the batter prior to setting in the oven.



**Figure 32** Variety of long and short pasta.

## F. DURUM WHEAT PRODUCTS

### (a) Pasta

Pasta (Figure 32) is a traditional food consumed in southern Europe that has now gained universal popularity. It is produced from a mixture of durum semolina and water, sometimes with the addition of eggs or flavour/colour components, which is extruded through a die. Noodles, particularly those containing eggs, and some specialty-filled products, are sometimes made by sheeting and cutting rather than extrusion.

Pasta is usually sold dried, but fresh or chilled product is also marketed. Pasta is dried under controlled temperature and humidity conditions to a low moisture level for storage and marketing.

Pasta is cooked to “al dente” firmness in boiling water. Sauces or other components of the meal are combined with the drained cooked pasta. Cooking time varies with pasta shape and thickness. Pasta should have a clear bright appearance, free from specks. Dried pasta should be free from checking (cracking), which is a function of the drying process.

Cooking and eating quality are important to the consumer. Pasta cooked to al dente should retain firmness if slightly overcooked and cooking loss should be minimal. Cooked pasta should have a creamy yellow colour and a smooth appearance. It should not be sticky.



**Figure 33** Couscous ready for consumption.

PHOTOS: T Westcott

### (b) Couscous

Couscous is a major staple food in North Africa, particularly in Morocco, Algeria and Tunisia. It was traditionally produced in the home by rubbing particles of durum semolina, which have been carefully moistened with water, with the palm of the hand. The resulting granules are then sieved to exclude larger agglomerates. The resulting granules are pre-cooked by steaming and then cooled and dried before use.

Couscous may be produced commercially by carefully mixing durum semolina and water into a crumbly dough mass. This mass is then broken using a system of mixers and sieves to obtain couscous particles. The particles, each an agglomerate of several semolina particles, are adjusted in size to produce different grades of couscous. The raw couscous is then steamed, dried, cooled and graded through sieves before packaging.

The traditional method for preparing couscous for consumption is to first moisten the grains with water and a small quantity of oil until completely absorbed. Couscous is cooked by steaming in the top of a couscousier (traditional cooking apparatus) over a sauce mixture of meat and/or vegetables (Figure 33). The cooked couscous is consumed with the sauce. Couscous may also be served with sugar as a dessert.

High-quality couscous must have an even particle size and the ability to maintain the integrity of the particles during steaming, without them sticking together. These characteristics, plus the ability to absorb large quantities of sauce without becoming sticky, combine to give the required mouth feel.

# Breeding for wheat quality

## (a) Defining breeding targets

A good wheat variety must meet the needs of all in the wheat value chain. That is, from the farmer, to the miller, to processors and manufacturers through to the consumer.

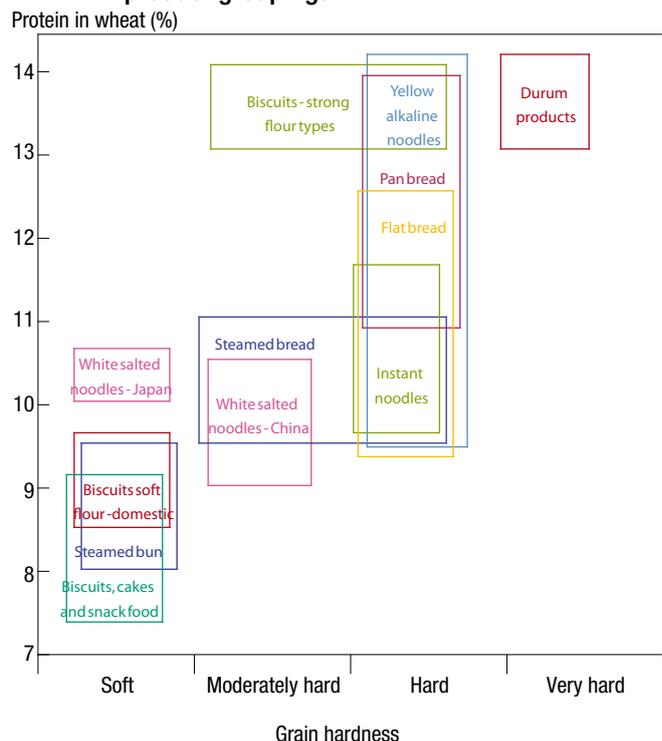
Wheat breeders need to understand the needs of all in the value chain and use the available genetics and quality testing capability to develop new varieties that will produce the high quality, attractive and nutritious bread, cake and pastry products demanded by consumers.

Successful wheat breeding is about having clearly defined and achievable targets. Agronomic attributes like plant height, straw strength, ease of threshing and maturity optimum for the target production region are essential components of all varieties.

A thorough knowledge of the environment of the target production region is critical, as this determines yield potential, the range and type of challenges the crop will experience from biological threats such as pests and diseases and soil and environmental stresses. Importantly, it also determines the quality type that can be reliably and profitably grown in that region. For example, in Australia, 80% of the wheat crop is grown in regions that receive less than 400 mm of annual rainfall. Furthermore, the rainfall varies across the wheat belt in its distribution, with southern regions being characterized by receiving most of the rainfall in the winter months compared with northern Australia, where most is received in the summer months. Rainfall sets yield potential and along with the onset of summer temperatures (more rapid in the northern region compared with the southern region) determines the quality types that can be reliably and profitably grown. Other major environmental influences effecting yield potential and quality are soil type, high temperature events during grain development and the occurrence of frost events during vegetative growth and or at flowering time.

The interplay between rainfall distribution and temperature, in the presence of susceptible varieties, creates the conditions for disease epidemics, and Australian breeders have to contend with a formidable list of diseases including, stem, leaf and stripe rust, yellow spot, septoria tritici blotch, septoria nodorum blotch, crown rot, take-all, common root rot, and 3 different soil-borne nematodes. The combinations of pests and diseases vary with production region, but the 3 rusts occur across all of Australia with devastating impact on yield and with grain of little to no value for processing into wheat-based products. Most diseases have an adverse impact on grain, processing and end-product quality.

**Figure 34** The relationship between grain hardness and protein content and various end product groupings.

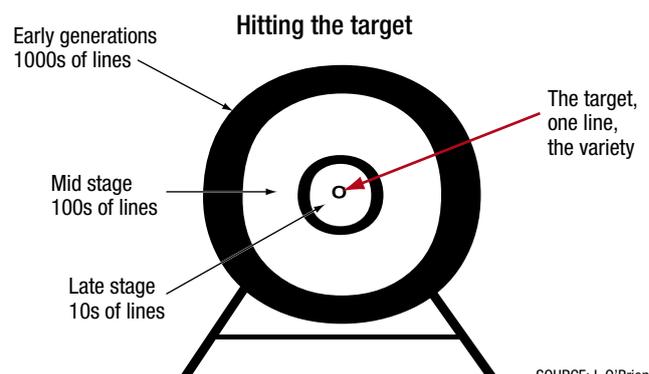


SOURCE: Modified from Moss by WQOG

## (b) Setting quality targets

Determining the quality target for a breeding program requires a thorough knowledge of the production region and its environment, but also an understanding of the requirements of others in the value chain who will buy, process and manufacture the wheat into end products.

**Figure 35** A diagrammatic representation of the stages of quality testing and the numbers of lines evaluated en route to producing a new variety.



SOURCE: L O'Brien



**Table 8** The types of quality tests deployed by wheat breeders at each stage of testing.

|                     | Hardness  | Protein content               | Protein quality                                     | End products   |
|---------------------|---|-------------------------------|---|--|
| Early stage testing | Grinding tests<br>NIR/NIT<br>Micro-milling  | Dumas/<br>Kjeldahl<br>NIR/NIT | SDS volume<br>Zeleny<br>volume<br>Pelshenke<br>time | No end<br>product<br>testing   |
| Mid stage testing   | NIR/NIT<br>Milling quality<br>(Quadrumat<br>or Buhler<br>yield and<br>flour colour)                   | Dumas/<br>Kjeldahl<br>NIR/NIT | Mixograph<br>Farinograph<br>Extensograph            | Test bake (pan<br>bread style)<br>Noodle sheet<br>colour<br>development<br>and stability |
| Late stage testing  | NIR/NIT<br>Bühler milling<br>(yield and<br>flour colour)<br>Ash %<br>Colour grade<br>Starch<br>damage | Dumas/<br>Kjeldahl<br>NIR/NIT | Farinograph<br>Extensograph<br>Alveograph           | Test bake (pan,<br>steamed and<br>flatbread<br>styles)<br>Noodle colour<br>and texture   |

With the target production region, quality type and how that grain will be utilized defined, it is now possible to start assembling the germplasm (the collection of genes available to wheat breeders) required to commence a breeding program.

Each target quality type, for example, the varieties that are eligible for receipt into the Australian Prime Hard Grade (APH), have unique combinations of genes that confer the quality attributes of that Grade. These include genes for high milling quality (high yield of white flour), protein and lipid composition (the strong and extensible dough properties needed to make a wide range of high-quality end products) and starch composition (important in textural properties of many wheat-based products). To develop APH quality wheat, the breeder can only use specific, elite gene combinations.

For the breeding program to be successful quality wise, the breeder needs to work with a cereal chemist who manages a laboratory that has all the equipment needed to screen breeding lines at the different stages of their development in the breeding process.

Deployment of quality testing needs to be done so that the fundamental components of quality are always assessed. These fundamentals are grain hardness or texture, the amount of protein (grain or flour protein content) and protein quality. Each has a major influence on how well any wheat will make end products, the ultimate assessment of wheat quality. Each fundamental is a measure in its own right, but each also has major influences over other properties measured using other tests. The relationship between these 3 basic parameters was visualized by Moss (1973) and

recently updated by the authors (Figure 34).

Grain hardness, or endosperm texture influences how the grain will perform during milling, with hard wheat suffering greater starch damage, resulting in their flours having higher water absorption. Soft wheat, on the other hand experience less starch damage and have lower water absorptions. Grain and flour protein content also indicate potential water absorption, dough strength and extensibility. Extensibility generally increases with protein content and it is desirable for dough strength to respond in this way as well. When combined with protein quality measures they all indicate the potential of a dough to perform under the stresses of dough mixing and the manufacture of end products.

Breeders handle thousands of lines per year and they need to be whittled down to the few lines that may end up as varieties. Consequently, a tiered quality evaluation system is used (Figure 35).

In the first stages of testing, where 1,000s of lines may be under evaluation, simple, rapid and cheap tests with a high daily throughput and predictive capacity are required. Breeding programs are major users of Near Infrared Reflectance (NIR) and Near Infrared Transmittance (NIT) instruments for determining important attributes like grain and flour protein content and grain hardness.

In the next stages of selection and evaluation, the mid- and late stages, where 100s and then 10s of lines are under evaluation, higher levels of sophistication are employed. This sees the use of milling procedures that more closely simulate what happens in a commercial flour mill, combined with the use of dough rheology testing (dough mixing and stretching characteristics) using laboratory instruments like the Mixograph, Farinograph, Extensograph and Alveograph. Testing of end products usually commences with a pan bread style test bake, using about 100g of flour to assess loaf volume potential, crust colour and crumb appearance and softness. At the final stages of testing extensive production of end products such as a range of pan bread styles, steamed and flatbreads, different types of noodle, and biscuits are evaluated.

Examples of the types of tests deployed at each stage of a typical breeding program are summarized in Table 8.

# Glossary of commonly-used cereal quality terms

**Alveograph:** a dough testing instrument that measures the resistance to deformation and extensibility of a clamped disc-shaped piece of dough by forming a bubble using air pressure applied from below the dough piece. It is used to assess the potential end-use quality of a flour.

**Baking absorption:** the amount of water, expressed as a percentage of flour weight, that must be added to make a dough for a specific baked product.

**Baking quality:** the ability of a wheat flour to produce a particular type of baked product.

**Buckiness:** a term used in the baking industry to describe dough that resist extension and are too tough for proper handling.

**CIE:** Commission Internationale de L'Eclairage.

**Classification:** the term used to describe the process by which wheat varieties are categorized into the traditional bulk classes of Australian wheat. These are Australian Prime Hard (APH), Australian Hard (AH), Australian Premium White (APW), Australian Standard White (ASW), Australian Standard White Noodle (ASWN), Australian Soft (ASFT), and Australian Durum (ADR).

**Conditioning (tempering):** the controlled wetting of grain followed by a resting period during which the added water toughens the bran and mellows the endosperm in preparation for milling.

**Colour stability:** The difference in lightness (brightness) values of a noodle sample measured over a specific time (usually 24 hours).

**Dockage:** the amount of unmillable or foreign material in a grain sample, which may readily be removed by mechanical means.

**Dough development time:** a measure of the time needed to develop a dough to a standard consistency. This is known as Farinograph development time.

**Dough stability:** a measure of dough strength using the Farinograph. It is the time that the dough maintains maximum consistency. It sometimes refers to the ability of the dough to tolerate under and over mixing.

**Extensibility:** the physical property of solid or semi-solid substances to stretch or increase in size. In Australia it is typically measured using an Extensograph. Dough extensibility is an important criterion for breadmaking quality.

**Extensograph:** an instrument that is used for measuring the extensibility and resistance to extension of a wheat flour dough mixed under standard conditions.

**Falling Number (or Hagberg) test:** a test to assess the soundness (freedom from sprouting and  $\alpha$ -amylase) of grain.

**Farinograph:** an instrument that mixes flour and water into a dough and produces a record of the resistance that the dough offers to the mixing blades. Used in the evaluation of the breadmaking quality of flour.

**Farinograph water absorption:** the percentage of water, expressed on a flour weight basis, required to develop the dough to a standard consistency.

**Flour ash:** the amount of mineral matter, usually expressed in %, and is determined by incinerating a weighed amount of flour and weighing the residue. Flour ash is an indicator of flour purity, indicating the level of bran and non-endosperm contamination in the flour.

**Flour colour:**

– **CIE L\***: indicates the lightness in CIE colour space and is commonly referred to as brightness

– **CIE a\***: indicates the value of red/green hue in CIE colour space

– **CIE b\***: indicates the value of the yellow/blue hue in CIE colour space

– **Kent Jones colour grade:** is a reflectance measurement taken on a flour-water slurry and values are indicative of flour brightness and bran contamination.

**Flour paste viscosity:** maximum viscosity during the heating phase of an Rapid Visco Analyser or Viscograph. Flour paste viscosity tests strongly reflect the pasting properties of the major component, starch, but also other components, including arabinoxylans and protein. Paste viscosity tests on flour, particularly the measurement of peak viscosity, are very sensitive to the effects of the starch-degrading enzyme  $\alpha$ -amylase, which is often associated with rain damage to the grain.

**Gelatinisation:** irreversible swelling of starch granules followed by formation of a viscous gel when starch is heated in excess water.



**Gluten:** the elastic proteinaceous material that remains after the water solubles and starch are washed out of a dough. Gluten content of flour is a measure of breadmaking quality.

**Grade:** a term used in the wheat industry in a number of contexts. Commercially “A Grade” is awarded after a load has been sampled and tested according to the receival standards, including classification, test weight, screenings and is best described as a “Commercial Grade”. These are the subject of regular review by the Grain Trade Australia (GTA, formerly NACMA) and are described using multiple acronyms such as ANW1, APW1, APW2 etc. These have little relevance to variety classification.

The term “grade” is used in variety classification to describe the quality of wheat varieties that have been classified according to processing criteria, end-use potential, and relative market value into one of the major marketing classes. These “Grades” relate to a particular state, region or port zone, and are listed in the “Wheat Variety Master List” published annually by the GTA.

**Grist:** the blend of wheat that is made up in the mill to produce a specific flour.

**Hard wheat:** wheat which has a vitreous endosperm generally considered an advantage for the production of breadmaking flours.

**Mixograph:** a recording dough mixer used for evaluating the dough mixing properties of a wheat flour. It measures and records the resistance of dough during mixing.

**Near Infrared Region:** is defined as the part of the infrared spectrum lying closest to visible light, that is, that part of the electromagnetic spectrum in the wavelength range 750 to 2600 nm.

**Physical dough tests:** flour quality tests based on the measurement of some physical dough property such as elasticity, viscosity and resistance to extension.

**RVA (Rapid Visco Analyser):** a rotational viscometer that continuously records the viscosity of a slurry under controlled temperature conditions. Is able to operate under varied temperature and shear conditions.

**Screenings:** the amount of small, cracked or broken grains and small foreign seeds that pass through a sieve or screen. In Australia, the sieve size for wheat is 2 mm. Australian flour millers consider screenings as the impurities in wheat

removed from the grain in the wheat cleaning section of the flour mill. See also unmillable material.

**Soft wheat:** a soft, opaque and less compact endosperm compared to hard wheat. Soft wheat is generally considered more suitable for the production of cake and biscuit flours.

**Sprouted grain:** grain which has begun to germinate, resulting in increased levels of the enzyme  $\alpha$ -amylase. This results in a softening of the grain, reducing its milling value and end-product quality.

**Starch damage:** mechanical damage to starch granules as a result of milling. Damaged starch granules are more susceptible to enzyme attack and have an increased level of water absorption.

**Test weight:** is the weight of a specific volume of grain and is usually determined using a Schopper chondrometer calibrated as kilogram/hectolitre (kg/hl). Test weight is used by the grain trade as an indication of milling potential of a parcel of wheat.

**1,000/kernel weight:** is the weight of 1,000 kernels of grain. It is a measure of grain size and density and is used as an indicator of the milling potential of wheat.

**Unmillable material:** where whiteheads, chaff and light foreign seeds remain on top of a 2 mm sieve after the screening process.

**Viscograph (or Amylograph):** a recording viscometer that measures the viscosity of an aqueous slurry of starch or flour as it is heated through a predetermined cycle. The viscosity is measured by the resistance that the heating slurry offers to a mixing paddle or pins.

**Water absorption:** the amount of water, expressed as percentage of flour weight, that is required to produce a workable dough.

**Yellow pigment content:** a measure of the naturally occurring xanthophyll pigments in flour.

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## Useful web sites

|  |  |
|--|--|
| ABB Grain  | <a href="http://abb.com.au">http://abb.com.au</a>                                      |
| Australian Bureau of Agricultural and Resource Economics (ABARE)         | <a href="http://www.abare.gov.au">www.abare.gov.au</a>                                 |
| Australian Grain Technologies  | <a href="http://www.ausgraintech.com">www.ausgraintech.com</a>                         |
| AWB Ltd  | <a href="http://www.awb.com.au">www.awb.com.au</a>                                     |
| CBH Group  | <a href="http://www.cbh.com.au">www.cbh.com.au</a>                                     |
| Department of Agriculture and Food, WA                                   | <a href="http://www.agric.wa.gov.au">www.agric.wa.gov.au</a>                           |
| Department of Agriculture, Fisheries and Forestry, Australia             | <a href="http://www.daff.gov.au">www.daff.gov.au</a>                                   |
| GrainCorp Operations Ltd   | <a href="http://www.graincorp.com.au">www.graincorp.com.au</a>                         |
| Grain Trade Australia (formerly NACMA)                                   | <a href="http://www.graintrade.org.au">www.graintrade.org.au</a>                       |
| Grains Research and Development Corporation                              | <a href="http://www.grdc.com.au">www.grdc.com.au</a>                                   |
| GoGrains   | <a href="http://www.gograins.com.au">www.gograins.com.au</a>                           |
| Intergrain   | <a href="http://www.intergrain.com">www.intergrain.com</a>                             |
| Longreach Plant Breeders   | <a href="http://longreachpb.com.au">http://longreachpb.com.au</a>                      |
| NSW Department of Primary Industries                                     | <a href="http://www.dpi.nsw.gov.au/agriculture">www.dpi.nsw.gov.au/agriculture</a>     |
| Pests and Diseases Image Library   | <a href="http://www.padil.gov.au/">www.padil.gov.au/</a>                               |
| Sydney University PBI Cereal Rust Laboratory                             | <a href="http://www.agric.usyd.edu.au">www.agric.usyd.edu.au</a>                       |
| The Cereal Chemistry Division of the Royal Australian Chemical Institute | <a href="http://www.raci.org.au/division/cereal/">www.raci.org.au/division/cereal/</a> |
| Wheat Exports Australia  | <a href="http://www.wea.gov.au">www.wea.gov.au</a>                                     |

## Appendix 1 & 2

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### Appendix 2 Acknowledgments: The Wheat Quality Objectives Group recognizes the corporate support and contributions from:

|   |                                 |
|---|---------------------------------|
| Grains Research and Development Corporation           |                                 |
| Department of Primary Industries, Victoria            |                                 |
| Australian Grain Technologies                         |                                 |
| Department of Agriculture and Food, Western Australia |                                 |
| AWB Limited   | CBH Group                       |
| Crackers Consulting                                   | Cereal Solutions Pty Ltd        |
| Solheimar Pty Ltd                                     | George Weston Foods             |
| Westcott Consultants Pty Ltd                          | Curtin University of Technology |



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