Cereal Foods World, January-February 2019, Volume 64, Issue 1

Analytical Testing to Support Australian Wheat Export Quality

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https://doi.org/10.1094/ CFW-64-1-1210

ABSTRACT

Wheat is the largest Australian grain crop, with a 10 year average production of almost 25 million tonnes. About 70% of the crop is exported, principally to markets in Asia. Australia's wheat classification and grading system relies on the additive effects of wheat variety (inherited characteristics) plus grain quality testing (environmental characteristics). A wheat variety's maximum classification is determined prior to release, and testing at the first point of receival establishes the class and grade for storage and, hence, suitability for end use. Grain quality is tested at up to 5 points within the supply chain before it is shipped to export markets or used by the domestic market. This article describes the analytical testing used and how it is integrated within the broader context of the Australian wheat industry.

Wheat is the largest Australian winter cereal crop, followed by barley, sorghum, oats, rice, and maize. Other important crops are canola and chickpeas. Wheat is grown in a crescent-shaped band known as the wheat belt (Fig. 1), which stretches from Queensland in the north and extends south through New South Wales and Victoria and in a westerly direction to South Australia and Western Australia. The wheat belt comprises an area of about 13 million ha that is generally within 400 km of the coast and has an annual rainfall of 300–600 mm.

Geographic and environmental conditions, such as soil type and weather, can vary widely from north to south and from one side of the continent to the other. The wide geographic spread means that during adverse seasons there is some buffer against impacts such as drought or preharvest rain that rarely affect the entire continent. Depending on the location and weather conditions, seed is sown during the April to June or July window. Most of the wheat varieties sown are spring wheat types, although there are small areas in which long season (winter) wheats are grown. Harvesting generally commences in the north (Queensland) in September and gradually progresses south down the east coast, with the harvest completed in the south (Victoria and South Australia) by late December or early January. In the west, the Western Australia harvest period usually extends from November through early to mid-January.

Average Australian wheat production in the 10 year period from 2009 to 2018 was 24.8 million tonnes (2). Yields during this period averaged 1.9 tonnes/ha, which was lower than the United States and Canada. Yield is constrained by rainfall prior to and during the growing period. The 2016 harvest was a record 32 million tonnes and was brought about by exceptionally high rainfall during the growing season, followed by dry harvest conditions. On average, domestic wheat users, which are mainly concentrated in eastern Australia, use 7–8 million tonnes for flour milling, feed, and seed. This leaves approximately 70% of the crop available for export to markets in more than 50 countries, principally in Southeast Asia, North Asia, the Middle East, the Indian subcontinent, North Africa, and Oceania. Indonesia is the largest market, followed by Vietnam, South Korea, Japan, and China. Each of these markets has different quality requirements depending on the main end use, be it fresh or wet yellow alkaline noodles, various styles of instant noodles, udon noodles, or a variety of breads. Approximately 90% of Australian wheat exports are in bulk, with the remainder shipped in containers. Western Australia produces some 34% of the Australian crop, but because most of the domestic consumption is on the east coast, it is the largest wheat exporting area. Western Australia also is conveniently closer to export markets in Asia and the Middle East, providing a freight advantage over wheat exported to these markets from the eastern states.

It has been 10 years since the Australian wheat export market was deregulated, which was the catalyst for the evolution of the industry functions that are currently in place. Today there are nine large marketers of grains, oilseeds, and pulses: three were previously bulk handling and storage entities that have added marketing to their businesses, the remainder include numerous minor trading companies, both domestic and international. Previously the domain of the single desk marketer Australian Wheat Board International (AWBI), marketers today accumulate, store, and transport their own grain within extensive bulk handling networks; engage directly with customers; and provide technical market support as requested. Quality, food safety, and environmental management systems are now integral parts of all activities within the supply chain.

Quality of Australian Wheat across the Supply Chain

Australian wheat has a reputation for high quality, especially in markets in Asia and the Middle East, where it is preferred for making flat breads and noodles. This is due to its low screenings, low moisture content, and white grain, producing high yields of clean, creamy-white flour. Noodles made from Australian wheat have excellent color, color stability, and texture. Wheat quality is managed and monitored across the supply chain (Fig. 2), and the procedures used to achieve this are detailed in the *Australian Grain Industry Code of Practice* (11).

The market-driven system of wheat varietal classification relies on feedback from purchasers of Australian grain, with the independent Australian Export Grains Innovation Centre providing grain quality analysis and market research and undertaking specific research projects. Outcomes are communicated to marketers, customers, breeders, and those involved with varietal

classification. Wheat breeding has transitioned from being a public sector activity in the 1990s to a consolidated mainly private sector activity, so breeders are very aware of the need to develop varieties with high yield for growers, appropriate disease resistance for the growing region, and specific quality for customer end uses. Wheat breeding is funded from the collection of end-point royalties (EPR), and varieties are registered for Plant Breeders' Rights. The EPR is decided by the breeder or seed commercializer and collected at the first point of sale.

Varietal integrity needs to be maintained by the wheat grower, who must sign a declaration of variety on delivery after harvest. Physical wheat quality is determined based on a sample taken from the grower's delivery to a customer or bulk handler and tested according to grade standards. It is the combination of variety (genotype) and physical wheat quality (environment and agronomic practices) that determines the grade allocated. Varietal integrity is rarely maintained after delivery (unless for special purposes), as each grade contains mixtures of varieties of similar or complementary quality type. Grain is then stored until required for shipping or delivery.

Measuring Varietal Quality and Classification of Varieties

In common with other wheat marketers, such as the United States and Canada, in Australia new wheat varieties are classified or categorized into a commercial class for marketing purposes. Classification decisions in Australia are based solely on quality, unlike Canada, where agronomic performance and yield are additional prerequisites. In Australia, which differs from the United States and Canada, major classes are not necessarily separated geographically, and all milling wheats are white grained. The decision to grow only white wheats for milling was made by the Australian government in 1923.

Wheat Quality Australia (WQA) is an independent nonprofit company jointly owned by the Grains Research and Development Corporation and Grain Trade Australia (GTA). WQA is responsible for the classification of new wheat varieties based on their particular wheat and flour quality attributes, processing, and suitability for end use. This "industry good" function was previously undertaken by AWBI prior to deregulation of the export market.

WQA controls the Wheat Varieties Master List, which lists the maximum classification for each variety in each classification zone. For the 2018/2019 season, there are almost 200 wheat varieties on the master list. Varieties remain on the master list until the quantity delivered falls below 0.1% of the total in a classification zone. Varietal quality is reviewed 10 years after initial classification for those varieties that are still popular to ensure their quality still meets the current requirements for their particular class.

There are four wheat classification zones (Fig. 1) representing different agro-ecological areas. The following seven wheat classes are classified for all zones. Australian hard (AH), Australian premium white, Australian standard white, and Australian general purpose (AGP) are hard wheat milling classes. The remaining classes are Australian durum (ADR), which is grown mainly in northern New South Wales, Queensland, and South Australia; Australian soft , which is grown mainly in New South Wales for the domestic milling and biscuit (cookie) industry; Australian noodle wheat, a special soft wheat grown mainly in Western Australia for export for udon noodle production in Japan and instant noodles in South Korea; and Australian feed (FEED), which is intended for use in feed.

There are two additional classes. Australian premium white noodle is a hard grained milling wheat specially grown in the western zone (Western Australia) and used to produce an export blend suitable for noodle manufacture in Asia. Australian prime hard (APH) is a premium, high-protein milling wheat suitable for specialty breads and noodles. It is currently classified only for the Northern and South Eastern classification zones (Queensland and New South Wales), but classification will be extended to other regions, probably in 2020. This change is the result of a 5 year research project to determine whether APH could become a national class.

Before a variety is classified and included on the Wheat Varieties Master List, the breeder must submit quality data for that variety (apart from those varieties intended for FEED). The WQA Variety Classification Panel, a group of independent wheat technical experts, reviews the quality data in order to allocate a maximum classification. Samples analyzed must originate from replicated field trials, and six appropriate data sets covering three seasons are required for a final classification in the primary zone. Additional trial data from other zones is required to decide classification in those zones; classifications for the same variety can differ between zones. Data from specified control varieties grown and tested at the same time are included for comparison purposes and to enable compilation of a descriptive quality profile for a new variety. Up to 30 individual quality parameters are considered. The range of tests required depends on the particular class and all include grain quality (test weight, 1,000 kernel weight, grain hardness, protein content, falling number, and screenings); milling quality (flour extraction rate, flour protein content, and flour ash); flour quality (tristimulus color or Agtron reflectance); dough properties (farinograph and extensograph); and flour paste viscosity (amylograph or rapid visco analyzer [RVA]). End-product testing is also dependent on the class and includes bread quality tested by one or more of three standard baking methods and yellow alkaline or udon noodles. Slightly different testing protocols are used for ADR, and a pasta-making test is required. Although not a prerequisite for classification, new udon noodle wheats are usually evaluated by Japanese flour millers or visiting Japanese experts.

Laboratories that submit data for wheat classification purposes must be proficiency tested, i.e., they must take part in ring tests conducted by WQA and satisfy the statistical performance requirements. Participants in the Proficiency Testing Rounds have been working toward harmonization and modification of methods, particularly for end products, as a way of reducing between laboratory variability and ranking of varietal characteristics.

Late-maturity α-amylase (LMA) is a genetic defect in wheat that, under certain environmental conditions, can cause elevated levels of α-amylase and, hence, low falling numbers in the absence of preharvest sprouting in genetically predisposed varieties. It is a requirement of the classification process that potential new varieties undergo at least two separate LMA phenotyping tests under prescribed conditions against control varieties prior to final classification being awarded. Because LMA testing has been a mandatory requirement for classification for more than 15 years, most varieties now grown in Australia do not express LMA or are

low risk.

Measuring Grain Quality at Receival

Most wheat is delivered after harvesting into storage at receival sites within the various bulk grain networks. Some wheat is stored on farm for later delivery to bulk handlers, to container packers, or directly to end users. Wheat trading standards (10,12) are set annually by GTA, an industry trade organization providing commercial rules and grain trading standards for the Australian grains industry. These standards are essentially used as receival standards for testing each load of wheat delivered and, together with varietal declaration, are used to determine the maximum bin grade (grade). There can more be than one grade within each class; for example, the APH class has two grades: APH1, with minimum protein content of 14.0%, and APH2, with a minimum protein content of 13.0%, which will be binned separately. Similarly, the AH class also has two grades: H1, with a minimum protein content of 13.0%, and H2, with a minimum protein content of 11.5%.

The receival testing process commences at the point of delivery, and each load must be presented to the sample stand for collection of a representative sample. Sampling is performed using either a sequentially opening manual probe or vacuum/pneumatic probe. Probes must be of sufficient length to reach, as closely as possible, the base of the truck. A sampling plan is used, with the number of probe points and size of the sample determined according to the size of the load (Table I). Testing is performed on the basis of each load delivered, with trucks and trailers considered separate loads. A varietal declaration must be made at the time of each delivery. Varietal declarations are audited, with varietal identity later confirmed by DNA analysis of random samples. Growers are informed of the correctness, or otherwise, of the varietal declaration after harvest and its suitability for use for future sowings. For each load, samples are composited, and a subsample is taken for testing for the specified wheat quality parameters of moisture, protein, test weight, screenings, and unmillable material. These key grain quality parameters and the methods used for harvest testing are detailed in Table I. Testing must be rapid and accurate, due to the large numbers of deliveries that need to be assessed during the peak of the busy harvest period, which lasts about two months. If rapid testing methods are used, results must be traceable back to original reference methods (Table I). Protein and moisture contents are measured by NIR/NIT (near infrared reflectance/near infrared transmittance constituent analysis), and protein is corrected to an 11% moisture basis (mb), which is close to the average moisture content of all Australian wheat receivals. This is in contrast to moisture corrections in other countries. For example, in Canada, wheat protein is reported on a 13.5% mb, and in the Black Sea region and some European countries, it is reported on a dry basis.

Internationally, most wheat is traded on the basis of protein content. Protein content, together with variety, is a major determinant of eligibility for inclusion in any particular Australian grade. Should the protein content of a delivery fall below the maximum for a particular grade, the wheat may be eligible for a lower grade, as detailed in Table II.

In Australia, a minimum test weight of 76 kg/hL is required for most milling grades (Table II), but in a normal season, test weights are well in excess of this minimum. Screenings are determined as material from a 0.5 L sample passing through a 2.00 mm slotted screen using a mechanical shaking device (Table I). Weight must be below 5% for most milling grades (Table II). Screenings include small, broken, and cracked grains and small foreign seeds (the latter can be measured separately). Unmillable material includes whiteheads with grains removed, chaff, backbone, and large seed pods not listed elsewhere in the standards. In Australia, screening differs from dockage, which is the term used elsewhere. In the United States, dockage is not a determinant of wheat grade. It is defined as all material other than wheat, as well as underdeveloped, shriveled, and small pieces of grain removed using a Carter Day dockage tester set up with a combination No. 2 riddle and No. 2 sieves (5).

Visual inspection is also required, for the various categories of defective grains and foreign seed and other contaminants (Table I). If "defective grains" (such as sprouted, stained, distorted, severely damaged, insect damaged, and over-dried) are detected, then, depending on the defect, a count is made using 300 grains from the top of the 2.00 mm screen or from a 0.5 L sample. There is a nil tolerance for sprouted grain, which means that falling number testing is performed immediately on deliveries at sites where sprouted grain is detected or where preharvest rainfall has occurred. Falling number results, when available, override sprouted grain counts. RVA is not used because falling number is the trading and grade specification. If a milling wheat fails to reach the minimum of 300 sec, it is downgraded to a lower grade, such as AGP1 (Table II).

"Foreign seed contaminants" include various seeds in 11 categories, and tolerances are usually the maximum numbers permitted per 0.5 L sample or, in the case of small foreign seeds, include those passing through the 2.00 mm slotted screen. In Australia, levels of foreign seed contamination are generally well below the maximum specified in the standards. The "other contaminants" category includes pickled grain, chemicals not approved for wheat, live stored grain insects, and objectionable materials, such as glass, metal, and sticks, for which there is a nil tolerance.

After allocation of a grade based on the results of quality testing and variety and completion of a declaration regarding pesticide application, the delivery truck is directed to the appropriate storage point. This is likely to be a silo, horizontal shed, or, increasingly as harvest sizes have increased in Australia, bunker storage. Temporary bunker storages have concrete, steel, or earth walls, and stored grain is covered with sealed tarpaulins. Storage capacity can be up to 100,000 tonnes.

Satisfying Trade Measurement Requirements and Ensuring Accuracy of Receival Testing

Instruments used for measuring protein content and bulk density (test weight) of all grains must comply with government regulations to ensure that measurements are accurate. The price paid is based on measured results, and deliveries failing to meet certain criteria will be allocated lower priced grades.

All protein measuring instruments must have mandatory "pattern approval," i.e., be confirmed as fit for purpose under the environmental conditions in which they are used. This is especially critical under Australian harvest conditions. Pattern approval includes a test procedure, maximum allowable error, and monitoring of a specified number of retained samples using a reference

instrument or chemical reference method. The maximum permissible error for instrumental wheat protein (usually NIR/NIT) compared with the Dumas method is ±0.4% on an 11% mb (14). Instruments used for trade purposes must be verified using certified reference materials (CRM), which are samples of grain with certified protein contents. This is done prior to harvest, on an annual basis or after repair or adjustment. The CRM should cover the operating range of protein expected under normal testing. Verification must be performed by a servicing licensee who is responsible for confirming the instrument complies with its certificate of approval and for testing instrument accuracy using CRM (15).

Operators of protein testing equipment have a daily test procedure in which standard reference samples are tested to a schedule and results are recorded and subject to audit. Bulk handlers and independent cereal laboratories also participate in regular industry-run collaborative testing rounds for key grain quality parameters to compare the accuracy and precision of test results across the industry.

Harvest Crop Reports

During harvest, the larger bulk handlers and marketers issue regular quality reports to grain owners, detailing the quality profile of the wheat received to date. Running samples from each grade at each receival site are dispatched to central laboratories, where they are composited to create port zone samples. A port zone sample is representative of all grain received in that grade and gives an indication of the wheat that will be shipped that season from a particular port. The samples are provided to grain owners and customers upon request for their own testing, either at their own laboratories or at independent cereal-testing laboratories. Full technical reports of testing are presented to overseas customers, usually at seminars, soon after harvest.

Individual marketer crop reports are compiled from testing port zone samples. Quality attributes tested include an extensive set of grain quality parameters, test milling, flour testing, and end-product testing. The appropriate end products are selected according to the class and grade and are representative of the main end products in various markets. These reports are utilized not only by domestic and international customers, but also by wheat breeders and those involved in wheat classification. An extract from the 2017/2018 crop report published by a large Australian bulk handler and marketer is shown in Table III. The differences between the classes and their most common grades, spread over a large geographic area, are shown in the report. It is common for functional variations to exist within the same grade of wheat, which could be shipped from one of up to 22 shipping ports. Most of the variability can be explained by differences between the most common varieties favored by growers, protein content, and seasonal or environmental conditions. The 2017/2018 season was considered a "typical" season and analytical results representative of Australian wheat quality.

Elsewhere, comprehensive crop reports are published in the United States (17) and Canada (4) that provide similar information on seasonal conditions, crop quality, trends, and market promotion.

Ensuring the Right Quality for Customers

Depending on the size of the current season's wheat crop, deliveries to domestic and international customers commence during harvest and continue up to the next harvest. Wheat is transferred from country silos or on-farm storage by train or truck to domestic flour mills, container packers, or seaboard shipping terminals. Data from quality testing during grain intake, plus the chemical residue status of the grain in storage, are used to decide which country sites will be used to assemble cargoes and deliveries. Grain quality is confirmed according to the key grain quality parameters on outturn from the country site and on intake at either a domestic customer's site or the shipping terminal.

For the domestic milling market, grain must also comply with the Food Standards Australia New Zealand (FSANZ) Food Standards Code (7), which regulates the use of ingredients in food manufacture and maximum residue limits (MRLs) for pesticides in foods. For the export market, grain quality is tested while grain is loaded to ship or container. Contracts detail grades, which can be based on GTA standards or according to export customer specifications. For example, a minimum protein content of 9% may be specified on an ASW cargo, which under GTA standards has no guaranteed protein minimum. Customers will sometimes specify additional quality testing, such as wet gluten, or have additional pesticide residue testing requirements. Quality must meet the specifications and standards required in the country of destination, including international standards such as Codex. Finally, a representative shipping or container sample is prepared and tested against the contract by an accredited independent laboratory.

Empty bulk vessels and containers are inspected by the Australian Government Department of Agriculture and Water Resources (DAWR) before loading, and further inspections for pests and contaminants are performed on the grain during loading. A phytosanitary certificate is issued when required by the importing country.

Managing the Risk of Chemical Residues and Environmental Contaminants

Grain hygiene and maintenance of safe storage that prevents insect infestation and water ingress are primary goals for all sectors within the Australian wheat supply chain. Management of grain hygiene may include maintenance of pesticide residue-free status or application of grain protectants in order to comply with industry MRLs. Compliance is tested by the National Residue Survey. This survey is funded by a statutory levy on growers and exporters and covers all cereal grains, pulses, and oilseeds, as well as milled components of wheat, soybeans, and maize. Samples are collected from each hold of bulk shipments, containers, and domestic mills and feedlots. Analytical testing is conducted for pesticide residues, herbicides, specific fumigants, and heavy metals. The compliance rate for MRLs in 2016/2017, according to Australian standards, was 99.8% for bulk export samples and 97.3% for container export samples, which is consistent with compliance rates for the past five years (6) and indicates good management practices across the supply chain.

Opportunities and Challenges

Consumption of wheat-based end products continues to increase in Asian markets, and the Australian industry is positioned to be part of the changes that are occurring in consumer preferences in the region. There is also increasing interest in both domestic and international markets in traceability across the supply chain, and this function is being integrated into data systems that allow real-time monitoring of stock movements and grain quality. Additional data are often required by Australian domestic flour mills, such as incidence of potential seed contaminants, including soy and lupin, which are considered allergens under Australian Food Standards (7) and must be removed as part of the cleaning process prior to flour milling.

The Australian grain industry has been an early adopter of new technology and was among the first to introduce NIR protein testing in the mid-1970s. Current interest is focused on identification of grain defects and contaminants, which rely on visual inspection. Development of more objective methods of image analysis is a subject of ongoing research, and trials have been conducted at harvest in Western Australia for the identification of moldy, stained, frosted, and sprouted grains.

Climate variability is always a challenge for Australian grain producers, who are likely to be affected by rising temperatures, particularly in southern areas. Prebreeding research is building in tolerance to environmental stresses such as heat, drought, and frost and improving water use efficiency and salinity tolerance traits, which will be available to wheat breeders in the development of future varieties.

Acknowledgments

I would like to thank Bob Cracknell, Fergus Dun, and Tas Westcott for their advice and helpful discussions during the preparation of this article, and Hugh Robertson, Wheat Quality Australia, for the provision of Figures 1 and 2.

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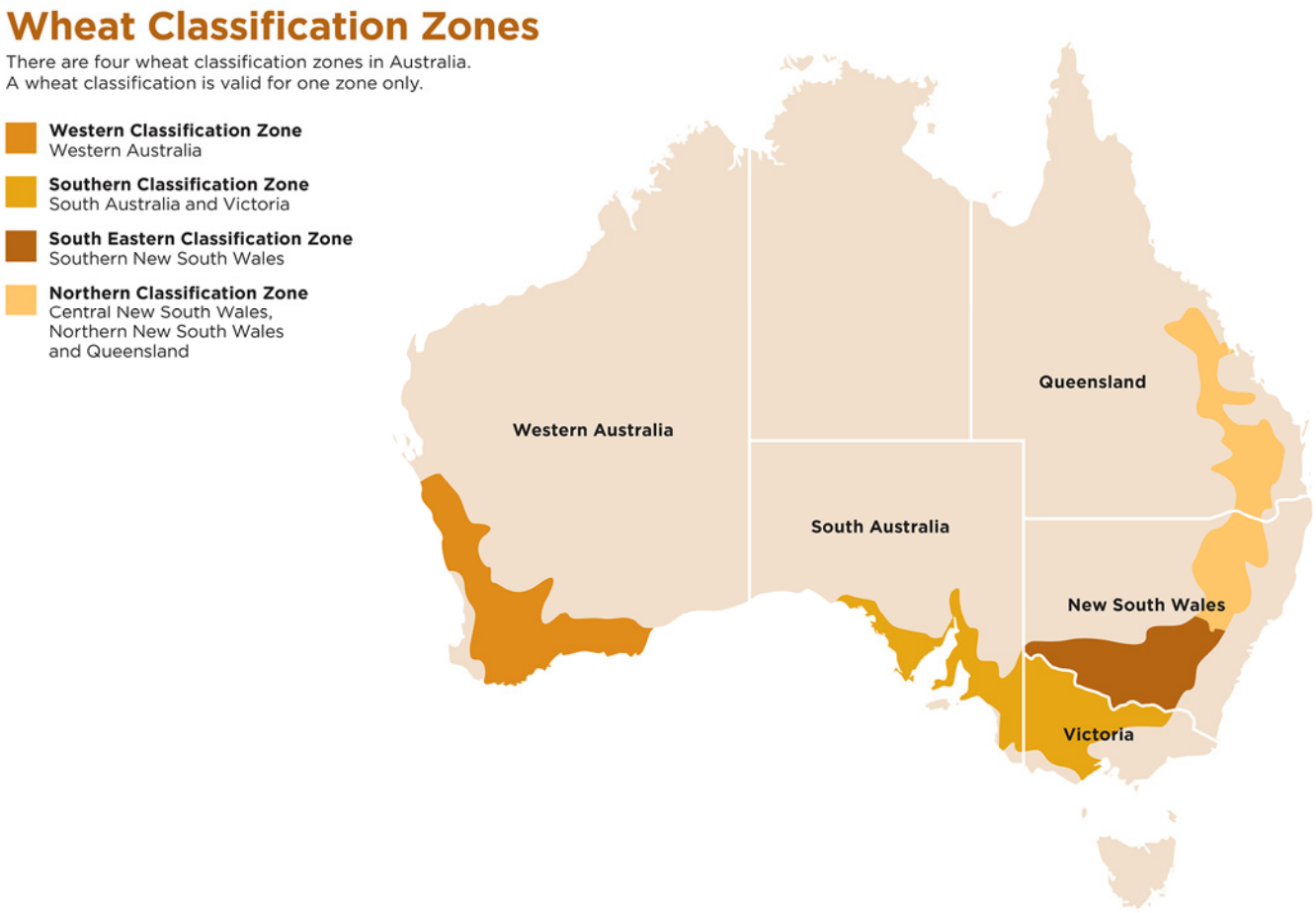

Fig. 1. Australian wheat growing areas and classification zones. (Reproduced with permission from Wheat Quality Australia)

Fig. 2. Stages in maintenance of quality across the Australian wheat supply chain. (Reproduced with permission from Wheat Quality Australia)

Table I. Methods used in quality assessment of Australian grain[a]

Tests	Parameter	Method	References	Reference for Analytical Method
Key grain quality parameters	Sampling	Manual, vacuum or pneumatic probe; minimum 3 L for deliveries < 10 tonnes	GTA (12)	GTA (12)
	Moisture	NIR/NIT (mostly whole grain)	GTA (12)	Oven-dried: AACCI Method 44-15.02 (1); GTA (12); NMI (14)
	Protein	NIR/NIT (mostly whole grain)	GTA (12)	Dumas: AACCI Method 46-30.01 (1); AGSA Method 02-03 (3)
	Test weight	Weight of 0.5 L sample, standard container filled using a height guide	GTA (12)	Chondrometer: AACCI Method 55-10.01 (1); GTA (12)
	Screenings	Material passing through 2.00 mm slotted screen after 40 shakes using an approved mechanical shaking device	GTA (12)	GTA (12)
	Unmillable material	Material retained above 2.00 mm slotted screen after 40 shakes using an approved mechanical shaking device	GTA (12)	GTA (12)
	Falling number	Falling number (sample weight not adjusted for moisture content or elevation)	GTA (12)	AACCI Method 56-81.03 (1); GTA (12)
Defective grain and contaminants	Defective grains	Visual, as detailed in references	GTA (9,12)	
	Foreign seed contaminants	Visual, as detailed in references	GTA (12,13)	
	Other contaminants	Visual, as detailed in references	GTA (9,12,13), Rees (16)	

[a] NIR/NIT = near infrared reflectance/near infrared transmittance constituent analysis; GTA = Grain Trade Australia; NMI = National Measurement Institute; AGSA = Australasian Grain Science Association.

Table II. Key quality parameters for classes and grades of Australian wheat[a]

Quality Parameter	Class[b]									
	APH	**AH**	**APW**	**APWN**	**ASW**	**ANW**	**ASFT**	**ADR**	**AGP**	**FEED**
Grade	APH2	H2	APW1	APWN	ASW1	ANW1	SFT1	ADR1	AGP1	FED1
Moisture (%), max	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Protein[c] (N×5.7) (%)	13.0 min	11.5 min	10.5 min	10.0–11.5	–	9.5–11.5	9.5 max	13.0 min	–	–
Test weight (kg/hL), min	76	76	76	76	76	76	76	76	68	62
Screenings[d] (%), max	5	5	5	5	5	5	5	5	10	15
Unmillable material (%), max	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.2	2.6
Falling number (sec), min	350	300	300	300	300	300	300	300	200	–
Varietal restrictions	Yes	Yes[e]	Yes[f]	Yes	Yes[g]	Yes	Yes	Yes	Yes[h]	No[i]
Grain hardness	Hard	Hard	Hard	Hard	Hard	Soft	Soft	Very hard	Hard	–
Grain color	White	White	White	White	White	White	White	White	White	White/red

[a] Data from Grain Trade Australia (10,12) and Delwiche and Miskelly (5).

[b] APH = Australian prime hard; AH = Australian hard; APW = Australian premium white; APWN = Australian premium white noodle; ASW = Australian standard white; ANW = Australian standard noodle; ASFT = Australian soft; ADR = Australian durum; AGP = Australian general purpose; FEED = Australian feed.

[c] 11% moisture basis.

[d] Material passing through 2.0 mm slotted screen.

[e] Restrictions include APH varieties that do not meet minimum protein requirements for APH.

[f] Restrictions include APH and AH varieties that do not meet minimum protein requirements for APH and AH.

[g] Restrictions include APH, APW, and AH varieties that do not meet minimum protein requirements for APH, AH, and APW.

[h] Restrictions can include downgraded APH, AH, APW, and ASW varieties.

[i] Some varieties have a maximum classification of FEED. Restrictions can include downgraded APH, AH, APW, ASW, and AGP varieties.

Table III. Australian crop report on wheat and flour quality for 2017/2018[a]

Class	APH	AH	APW	APW
Grade	APH2	H2	APW1	APW1
State	New South Wales	New South Wales	Victoria	Western Australia
Port zone	Newcastle	Port Kembla	Geelong	Kwinana
Minimum protein (%)	13	11.5	10.5	10.5
Wheat				
Test weight (kg/hL)	81.9	81.9	80.8	82.2
1,000 kernel weight (g)	35.8	38.0	40.2	42.0
Grain hardness (psi)	13	15	15	12
Protein (N×5.7, 11% mb)	13.6	12.0	11.0	10.5
Moisture (%)	10.7	10.6	10.3	9.9
Ash (%,11% mb)	1.36	1.25	1.20	1.24
Falling number (sec)	410	435	417	449
Screenings, 2 mm (%)	1.8	0.9	1.1	1.6
Foreign material (%)	0.1	0.0	0.2	0.0
Flour extraction (%)	77.8	77.9	77.7	77.0
Flour				
Protein (N×5.7, 14% mb)	12.8	11.2	10.0	9.6
Wet gluten (%)	35.3	33.0	27.1	27.3
Gluten index	96	97	97	94
Flour ash (%)	0.45	0.42	0.43	0.43
Farinogram				
Water absorption (%)	63.9	63.2	61.2	64.4
Development time (min)	6.0	6.7	4.8	4.6
Stability (min)	7.1	9.6	7.6	7.3
Extensogram (45 min pull)				
Extensibility (cm)	25.2	22.5	18.9	18.3
Maximum height (BU)	360	390	350	310
Viscogram				
Peak viscosity (BU)	490	500	400	470
Baking test (straight dough)				
Volume (cm^3)	990	825	810	710
Score (%)	90	86	83	79
Yellow alkaline raw noodle sheet color				
Minolta *L* (T^b = 30 min)	80.3	82.1	82.0	82.8
Minolta *b* (T^b = 30 min)	26.8	27.4	26.9	27.4
Color stability	11.5	12.0	10.4	9.3

[a] Data and analytical methods from GrainCorp (8). APH = Australian prime hard; AH = Australian hard; APW = Australian premium white.
[b] T = time after sheeting.