The Mixing Requirement of the Australian Hard Wheat Cultivar, Dollarbird

J. R. OLIVER and H. M. ALLEN[1]

Cereal Chem. 71(1):51–54

ABSTRACT

Hard wheats recently released in Australia exhibit an undesirable increase in mixing requirement concomitant with a desired increase in dough strength characteristics. Farinograph and extensigraph measurements on the cultivar Dollarbird indicated that it combined short development times with excellent dough strength. Measurements were made using: 1) the farinograph at 180 rpm rather than the conventional 60 rpm, 2) a National pin mixer as an alternative to the farinograph, and 3) a compressive stress test as an alternative to the extensigraph test. These measurements indicate that the mixing requirement of Dollarbird was no different from other hard wheat cultivars of similar dough strength.

In breadmaking technology, dough strength is generally measured from extensigraph parameters. Recording dough mixers such as the farinograph and mixograph also yield parameters (dough breakdown, band thickness, stability) that are indicators of dough strength. Generally, flours (or wheat cultivars) that produce stronger doughs require longer mixing times to achieve development (Shuey 1972).

Provided the appropriate balance of extensibility and resistance is maintained, additional dough strength has advantages. However, dough development time can become excessive. Consequently, in developing new wheat cultivars for breadmaking, it is necessary to compromise between improving strength and increasing development time. The recently released Australian cultivar, Dollarbird, appears to successfully achieve this compromise with strong dough characteristics and a short development time. Some of its properties are discussed here.

MATERIALS AND METHODS

Wheat Analytical Tests

Wheat samples were obtained from 1989 sown trials at Yanco (~10.5% protein) and Wagga Wagga (~12.5% protein). Test weight was determined using a Franklin chondrometer. Thousand-kernel weight was determined by weighing 1,000 grains counted by a Numigral seed counter (Tripette et Renaud, Paris, France). Protein measurements were performed using a Technicon Infra-analyser 400 (Bran and Leubbe, Nordenstadt, Germany) calibrated against a Kjeldahl procedure (method 46-12, AACC 1983) and reported as N × 5.7. Grain hardness was determined as pearling resistance by the method of Chesterfield (1971).

Milling

Wheat (3 kg) was conditioned to 15.0% moisture level for 24 hr. An extra 0.5% moisture was added 0.5 hr before milling in a Buhler MLU202 test mill (Buhler-Miag, Uzwil, Switzerland). Flour extraction was calculated on a total products basis.

Mixing

Dough mixing studies were performed using a Haake Buchler System 90 torque rheometer (Haake Buchler Instruments, Saddle Brook, NJ) fitted with a 300-g farinograph bowl (Brabender OHG, Duisberg, Germany) water-jacketed to 30°C. With this configuration, the torque rheometer is essentially a variable-speed farinograph. Water was added to produce the center of the peak at 0.5 Nm (equivalent to farinograph consistency of 500 BU) at 60 rpm. Mixing speeds (the speed of the slow paddle in the farinograph bowl) of either 60 or 180 rpm were used with the same water addition. Measurements of torque, work (determined as joules per gram of flour), and time were recorded using System 90 Thermoplastic software. From the mixing curve obtained, the end of the plateau period was subjectively determined as the first signs of weakening at the center of the curve peak. Dough development time and work input were measured to this point (Oliver and Allen 1992) unless otherwise specified.

Alternative mixing information was obtained from a National pin mixer (National Mfg. Co., Lincoln, NE) used for extensigraph measurements and test baking. Power consumption was measured using a current-sensing power transducer. The average power used was recorded 10 times per second on an Osborne 386 personal computer equipped with a Metrabyte DAS-8 analog-to-digital converter using Powermix software (Lothain Holdings P/L, Sydney, Australia). Work requirement was calculated by integrating the power consumption measurements.

Compressive Stress Tests

Relaxation times were measured on flour-water-2% salt doughs using a compressive stress test modified from the method of Frazier et al (1973). Doughs were mixed in the torque rheometer at either 60 or 180 rpm. Dough (15 g) was scaled off, hand-rounded, shaped spherically, and allowed to rest in a 500-ml decor polyethylene screw-top container for 45 min at 30°C. At the end of the rest period, the dough was compressed between parallel plates in an Instron 1140 food texture analyzer (Instron Ltd, High Wycombe, England) to 400 gF (crosshead speed 50 mm/min, chart speed 500 mm/min). Then compression was stopped but maintained, and the dough was allowed to relax. The time (seconds) taken for the measured force to decrease to 100 gF was recorded as the relaxation time. Maximum relaxation time was determined by mixing successive doughs for increasing times.

Extensigraph Measurements

Extensigraph test doughs were prepared by mixing flour-water-2% salt doughs in the National pin mixer (110 g of flour) for 2, 3, or 4 min. The water addition was determined from the RACI (1988) extensigraph measurement (using a farinograph bowl to produce a dough of 500 BU consistency exactly 5 min after water addition). After mixing, a single 150-g dough piece was scaled off, rounded, shaped, rested for 45 min at 30°C in the extensigraph cabinet, and stretched on the extensigraph. Area under the extensigraph curve was determined by integrating the rhombuses on the chart paper.

Test Baking

The test baking formula was: flour 110 g, yeast 2.5 g, sodium chloride 2 g, ammonium chloride 0.1 g, malt extract 0.6 g. The amount of water added was determined in mixing studies mentioned above. Doughs were mixed in the National pin mixer (110 g of flour) for various times. After mixing, doughs were fermented for 1 hr at 30°C in the decor polyethylene screw-top containers, hand-knocked, proofed for 12 min at 30°C, molded in a Mono universal molder (Automatic Bakery Machinery, Swansea, England) at pressure 32 and gauge setting 1, and tin-proofed for 44 min at 33°C and high humidity. Baking was done in a Simon rotary test oven (Henry Simon Ltd, Stockport, England) at 225°C for 20 min.

[1]Agricultural Research Institute, Wagga Wagga, NSW, Australia.

This article is in the public domain and not copyrightable. It may be freely reprinted with customary crediting of the source. American Association of Cereal Chemists, Inc., 1994.

Statistical Analysis

Statistical analysis was performed using Genstat V (Laws Agricultural Trust, Rothamstead, UK).

RESULTS AND DISCUSSION

Wheat Samples

Cultivars assessed were Dollarbird, Banks, Osprey, Vulcan, Sunstar, and Hartog. Except for Hartog, these cultivars were recommended for general sowing in the Yanco–Wagga Wagga area of southern New South Wales and were well adapted to the area. Hartog was included because the domestic milling industry has identified it as having an undesirably long mixing requirement. Dollarbird, Sunstar, and Hartog are hard wheat cultivars with strong dough properties. Banks and Osprey are hard wheat cultivars with less strong dough properties. Banks has a low mixing requirement and is preferred by the Australian domestic breadmaking industry. Vulcan dough strength is at the lower limit of that preferred by the Australian breadmaking industry.

Grain characteristics of the samples are shown in Table I. In both trial sets, Banks was slightly softer and had slightly smaller kernel weight than those of the other cultivars. Sunstar and Hartog were the two hardest cultivars. The principal difference between the two sets was in protein content and farinograph water absorption.

Farinograph Tests

The accepted procedures for the farinograph use a flour-water system. The accepted procedures for the extensigraph measurements use a flour-water-2% salt system that seems to better relate to a test-bake bread formula in terms of work requirement (Oliver and Allen 1992). Therefore, to enable more direct comparisons between farinograph, extensigraph, and the other methods, a flour-water-2% salt system was used throughout.

Table II compares the dough development time and work input measurements when mixed in the farinograph bowl at either 60 or 180 rpm.

The peaks obtained from the Yanco trial set were very sharp, and measurements could be made to an exact peak position. At 60 rpm, the cultivars exhibited a large range in both dough development time and work input. Each measurement ranked the cultivars in the same order. Dollarbird had the lowest dough development time and was similar to Banks in work requirement. At 180 rpm, the range in development time was quite narrow, whereas the range in work input remained large. Although each measurement still ranked the cultivars in the same order, Dollarbird was not ranked lowest in this case. At 180 rpm, the other five cultivars maintained their relative ranking as in the 60 rpm mixings, but Dollarbird appeared to be more similar to Osprey than to Banks.

Quite different results were exhibited by the samples from the Wagga Wagga trial set, which was not unexpected given the higher protein content. At 60 rpm, the farinograms of each cultivar contained an obvious plateau period that made the peak position less well-defined. The ICC (1980) and AACC methods both recommend that dough development time be measured to the first signs of weakening (the end of the plateau period). The RACI method is less precise and could be interpreted as meaning either the beginning or the center of the plateau period. Dollarbird had the shortest time to the beginning of the plateau period (according to the RACI method; Table III), but it had the longest time to the end of the plateau period (according to the ICC or AACC method; Table II). Thus, depending on the method chosen, Dollarbird could be considered as having the shortest or the longest development time of the set.

The Wagga Wagga data (Table II), like the Yanco data, showed that development time or work input ranked the cultivars similarly. Although the ranked order was quite the same at both 60 and 180 rpm, it was quite different from that of the Yanco set. Dollarbird had the highest development time; Vulcan had the lowest.

Unlike the Yanco trial set, the work input measured at 60 rpm was almost identical to that measured at 180 rpm. Mixing speed was previously demonstrated to increase as the development time decreases, but the work input remains constant, particularly that measured to the end of the plateau period (Stamberg and Bailey

TABLE I
Grain Characteristics[a] for Samples from Yanco and Wagga Trial Sets[b]

	TW	KW	GP	HD	FE	FP	FWA
Yanco							
Dollarbird	84.1	33.2	10.7	4.8	74.7	9.8	64.0
Sunstar	85.0	34.0	10.6	5.0	73.8	9.6	62.0
Banks	84.4	30.7	10.8	4.5	74.7	9.8	62.0
Hartog	83.8	32.8	10.3	5.1	74.8	9.5	65.0
Osprey	84.7	34.0	11.9	4.8	74.8	10.8	63.5
Vulcan	85.0	33.6	10.3	4.7	73.4	9.4	61.8
LSD[c]	0.7	1.7	0.8	0.3	...	0.7	1.8
Wagga Wagga							
Dollarbird	82.7	34.1	12.4	4.9	73.7	11.3	66.4
Sunstar	82.5	33.8	12.9	5.1	73.1	11.8	65.1
Banks	82.5	31.1	12.4	4.5	74.4	11.4	65.6
Hartog	83.2	33.1	12.8	5.2	74.4	11.7	64.1
Osprey	83.5	34.2	12.7	4.8	74.0	11.7	65.8
Vulcan	82.5	33.8	12.3	4.7	73.6	11.4	64.0
LSD	0.7	1.6	0.3	0.3	...	0.4	1.2

[a] TW = test weight (kg/hl), KW = kernel weight (grams per 1,000 kernels), GP = grain protein (N × 5.7), HD = hardness (pearling resistance), FE = flour extraction (% total products basis), FP = flour protein (N × 5.7), FWA = farinograph water absorption (%).
[b] Mean value of duplicate determinations reported except for FE for which only a single determination is reported.
[c] Least significant difference.

TABLE II
Dough Development Time (DDT) and Work Input (WI) Required to Mix a Flour-Water Dough to the End of the Plateau Period in a Farinograph Bowl Running at Either 60 or 180 rpm[a]

	DDT, min		WI, J/g	
Trial Set	60 rpm	180 rpm	60 rpm	180 rpm
Yanco				
Dollarbird	1.7	1.2	19	71
Banks	2.1	1.0	19	58
Osprey	3.0	1.1	35	71
Vulcan	5.3	1.3	64	84
Sunstar	6.6	1.4	92	102
Hartog	7.9	1.6	108	120
Wagga Wagga				
Dollarbird	15.7	3.0	191	195
Banks	9.2	1.7	117	98
Osprey	13.0	2.8	179	180
Vulcan	5.0	1.0	68	62
Sunstar	7.3	1.5	101	110
Hartog	12.5	2.7	155	155

[a] Mean value of duplicate determinations. Least significant difference for DDT of the Yanco trial set = 0.3 min; Wagga Wagga trial set = 0.4 min. Least significant difference for WI of the Yanco trial set = 15 J/g; Wagga Wagga trial set = 23 J/g.

TABLE III
Dough Development Time (DDT) for Samples from the Wagga Wagga Trial Set Measured According to the RACI Farinograph Method[a]

Sample	DDT, min
Dollarbird	3.5
Banks	4.5
Vulcan	4.5
Osprey	5.0
Sunstar	6.0
Hartog	7.5

[a] Time (minutes) to where the center of the curve (60 rpm) first levels off on the 0.5-Nm line. Mean result of duplicate determinations. Least significant difference = 1.8 min.

1938; Kilborn and Tipples 1972a,b; Frazier et al 1975; Oliver and Allen 1992). The Yanco data set appeared to challenge this.

What we observed as the main peak in the 60-rpm farinograph appears as a preliminary shoulder to a secondary peak revealed at higher speeds. This secondary peak appears to be more relevant to gluten development, although, as Frazier (1979) has demonstrated, it is transient in nature and does not necessarily indicate optimal mixing requirement.

In a 60-rpm farinogram, in strong flours, this secondary peak is observed as the end of the plateau period. Sometimes, it is observed as the second peak in the phenomenon of double development. In weaker flours, this secondary peak occurs partway along the breakdown of the curve, sometimes manifesting as a mere bump, but often indistinguishable.

For the Yanco trial set at 60 rpm, the gluten is either not sufficiently strong or is insufficiently developed to enable the secondary peak to make an observable impression on the mixing curve. This is consistent with the work of Kilborn and Tipples (1972a), who demonstrated that critical levels of mixing intensity and work input must be exceeded to properly develop a dough. At 180 rpm, the secondary peak is measurable as the main peak in the curve. We suggest, therefore, that for the Yanco trial set, the work input measurements differ because the peak at 60 rpm is not created by the same phenomenon as is the peak at 180 rpm.

We further suggest that the samples from the Wagga Wagga trial set were sufficiently high in protein and sufficiently strong for the secondary peak to contribute to the 60-rpm curve by extending the initial peak to create the plateau period. In this case, the work input measured to the end of the plateau period at 60 rpm was the same as that measured at the 180-rpm peak because the same phenomenon was responsible for both.

Dollarbird had the longest time to the end of the plateau period in the 60 and 180 rpm measurements of the Wagga Wagga trial set, and it was similar to the other cultivars in the 180 rpm measurements of the Yanco trial set. This is taken as evidence that its mixing requirement was at least as long as that of the other cultivars in these trial sets. However, this is in contrast to the often-observed behavior of Dollarbird exhibiting a short farinograph development time.

Dollarbird has the ability to hydrate rapidly, but its gluten development time and work input requirement are as long as those of other wheats of comparable strength. In the conventional (60 rpm) farinogram, some studies suggest that it is the hydration peak that dominates (Frazier et al 1975, Frazier 1979). Unless the gluten has sufficient strength to create an observable plateau period, dough development time will be measured as the time to this hydration peak. The apparent short dough-development time of Dollarbird is thereby an artifice of farinogram measurement and what it reveals. Further evidence to support this contention was gathered from the compressive stress tests, extensigraph tests, and test baking.

TABLE IV
Maximum Relaxation Time (RT) and Corresponding Work Input (WI) for Samples Mixed in a 300-g Farinograph Bowl[a]

	RT, sec[b]		WI, J/g[c]	
Trial Set	**60 rpm**	**180 rpm**	**60 rpm**	**180 rpm**
Yanco				
Dollarbird	35	40	100	102
Banks	31	35	90	96
Osprey	27	33	108	112
Vulcan	29	34	99	99
Sunstar	37	49	111	111
Hartog	30	33	105	105
Wagga Wagga				
Dollarbird	48	65	175	200
Banks	38	63	160	160
Osprey	31	66	160	190
Vulcan	25	35	105	105
Sunstar	38	57	150	200
Hartog	41	80	220	275

[a] Mean value of duplicate determinations.
[b] Least significant difference for the Yanco trial set = 3.5 sec, Wagga Wagga trial set = 4.0.
[c] Least significant difference for the Yanco trial set = 10 J/g, Wagga Wagga trial set = 18 J/g.

TABLE V
Extensigraph Area (cm^2) for Samples Mixed for 2, 3, or 4 min in the National Pin Mixer[a]

	Mixing Time, min		
Trial Set	**2**	**3**	**4**
Yanco			
Dollarbird	105	115	153
Banks	101	107	91
Osprey	139	127	117
Vulcan	93	96	87
Sunstar	82	97	108
Hartog	122	146	136
Wagga Wagga			
Dollarbird	132	135	142
Banks	109	118	116
Osprey	125	128	135
Vulcan	105	118	95
Sunstar	139	183	172
Hartog	90	126	149

[a] Mean value of duplicate determinations. Mixings were duplicated. One dough piece from each mixing was extensigraphed. Least significant difference for each trial set = 10 cm^2.

Compressive Stress Tests

Frazier et al (1975) has shown that the maximum relaxation time measured by a compressive stress test was at a work-input level related to the dough strength of a cultivar.

Table IV lists the maximum relaxation time and corresponding work requirements. In each trial set, the maximum relaxation time after mixing at 60 rpm occurred at about the same work-input level as that for mixing at 180 rpm. The magnitude of the maximum relaxation times for Dollarbird indicate that it is among the stronger cultivars in the group. The maximum relaxation times for Vulcan showed it to be at the lower end of the dough-strength range.

The work requirement measurements indicate that Dollarbird had a mixing requirement similar to that of other wheats of similar strength. Vulcan measurements were among the lowest at both sites. Banks was lowest at Yanco but similar to most others at Wagga Wagga.

Extensigraph Tests

Extensigram area is an indicator of strength (Munz and Brabender 1940). At both sites, Dollarbird had one of the larger extensigram areas at each mix time (Table V). Its extensigram area increased as mixing time increased. This again indicated that it has both high strength and a long mixing requirement. Banks and Vulcan had the lowest extensigram areas at all mix times, indicating low dough strength compared with those of the other cultivars. Both exhibited maximum dough strength at 3 min, indicating a shorter mixing requirement. Osprey showed a decline in extensigram area with increased mixing at Yanco but a slight increase at Wagga Wagga.

Test Baking

The test-bake procedure used was neither a strictly mechanical dough development system nor a bulk fermentation system. It employed aspects of each in that it used a high work-input mixer without the associated dough improvers. There is a considerable fermentation period (1 hr) involved, but not long enough to enable doughs that are underdeveloped to mature sufficiently to produce a satisfactory loaf. The National pin mixer suitably develops doughs of flours similar to the ones tested in 2–3 min.

Experience with quality evaluations of wheat breeding material has shown that the bake procedure used (rapid, intense mixing

TABLE VI
Loaf Volumes (cm^3) for Samples Mixed for 2, 3, or 4 Min in the National Pin Mixer[a]

Trial Set	Mixing Time, min		
	2	3	4
Yanco			
Dollarbird	565	515	440
Banks	590	550	525
Osprey	585	555	555
Vulcan	585	565	550
Sunstar	550	520	510
Hartog	555	535	430
Wagga Wagga			
Dollarbird	570	630	615
Banks	610	620	585
Osprey	625	665	675
Vulcan	620	550	520
Sunstar	550	670	655
Hartog	485	550	575

[a] Mean value of duplicate determinations. Least significant difference for each trial set = 21 cm^3. Standard deviation = 10.

followed by the fermentation period) gives suitable discrimination of baking quality. It enables the selection of doughs with quality suitable for Australian markets. Doughs with short mixing times are readily overmixed, but, if their gluten quality is satisfactory, they can recover in the fermentation phase. Doughs requiring longer mixing times are somewhat undermixed, and the fermentation time is too short to enable complete development. Thus, while the procedure is not a simple test of mixing requirement, it does incorporate mixing requirement as an important contributor to the measured baking quality. The best single index of that baking quality is loaf volume.

In the sample set from Wagga Wagga (Table VI), Hartog and Osprey produced the best loaf volumes after 4 min of mixing; Dollarbird, Sunstar, and Banks after 3 min of mixing; and Vulcan after 2 min of mixing. Dollarbird showed a substantial increase in loaf volume after 3 min of mixing compared with 2 min of mixing. This indicated that Dollarbird was benefiting from the extra mixing requirement rather than recovering from an overmixed state. Hartog and Sunstar showed similar large responses when mixing time was increased from 2 to 3 min. Both Banks and Vulcan showed a requirement for a short mixing time. The maximum loaf volume of Banks occurred at 3 min, but this was not significantly different ($P > 5\%$) from that at 2 min. The loaf volume of Vulcan declined with increasing mixing time.

For the sample set from Yanco, the loaf volumes of all cultivars decreased with increasing mix time. This could be expected, given the low work requirement (approximately 100 J/g) to maximum relaxation time measured for all cultivars in the Yanco trial set (Table IV). This implies that their work input requirement is close to 100 J/g. The National pin mixer, with 110 g of flour, imparts 97 ± 3 J/g per minute of power. Even allowing for considerable inefficiencies within the mix system, a 2-min mix is likely to exceed the work requirement for this trial set.

CONCLUSIONS

Dollarbird is a strong, hard wheat cultivar. Its dough development time, as measured on the farinograph, particularly by the RACI method, indicates that it has a short mixing requirement. However, other measurements indicate that it has a mixing requirement similar to other strong, hard wheat cultivars. The inconsistency is partly due to the manner in which the RACI measurement is described. Measuring to the first signs of weakening, as the AACC and ICC methods recommend, would provide better information on where the farinogram displays a plateau at the peak. Alternatively, measurements made at 180 rpm would be an improvement.

ACKNOWLEDGMENT

We gratefully acknowledge the financial assistance of the Australian Wheat Research Council in supporting this work.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. Method 46-12, approved October 1976, revised October 1986. Method 54-10, approved April 1961, revised October 1982; Method 54-21, approved April 1961, revised October 1982. The Association: St Paul, MN.

CHESTERFIELD, R. S. 1971. A modified barley pearler for measuring hardness of Australian wheats. J. Aust. Inst. Agric. Sci. 37:148-151.

FRAZIER P. J. 1979. A basis for optimum dough development. Baking Ind. J. 12:20-27.

FRAZIER, P. J., LEIGH-DUGMORE, F. A., DANIELS, N. W. R., RUSSELL EGGITT, P. W., and COPPOCK, J. B. M. 1973. The effect of lipoxygenase action on the mechanical development of wheat flour doughs. J. Sci. Food Agric. 24:421-436.

FRAZIER, P. J., DANIELS, N. W. R., and RUSSELL EGGITT, P. W. 1975. Rheology and the continuous dough making process. Cereal Chem. 52:106r-130r.

ICC. 1980. Standard 114, Method for using the Brabender Extensigraph; Standard 115, Method for using the Brabender Farinograph. International Association for Cereal Chemistry: Vienna.

KILBORN, R. H., and TIPPLES, K. H. 1972a. Factors affecting mechanical dough development. I. Effect of mixing intensity and work input. Cereal Chem. 49:34-47.

KILBORN, R. H., and TIPPLES, K. H. 1972b. Factors affecting mechanical dough development. II. Implications of mixing at a constant rate of energy input. Cereal Chem. 49:48-53.

MUNZ, E., and BRABENDER, C. W. 1940. Extensigrams as a basis of predicting baking quality and reaction to oxidising agents. Cereal Chem. 17:313-331.

OLIVER, J. R., and ALLEN, H. M. 1992. Prediction of breadbaking performance using the Farinograph and Extensograph. J. Cereal Sci. 15:79-89.

RACI. 1988. Official Testing Methods of the Royal Australian Chemical Institute, Cereal Chemistry Division. The Institute: Parkville, Victoria, Australia.

SHUEY, W. C. 1972. Farinograph Handbook. Am. Assoc. Cereal Chem.: St. Paul, MN.

STAMBERG, O. E., and BAILEY, C. H. 1938. Relationship of mixing speed to dough development. Cereal Chem. 15:739-748.

[Received November 30, 1992. Accepted September 7, 1993.]