VALUE ADDED WHEAT CRC

FINAL REPORT

Project: 2.1.5
GRDC Project CWQ12

Australian Wheat for the Sponge and Dough Bread Making Process

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A REPORT TO THE GRDC and VALUE ADDED WHEAT CRC

Australian Wheat for the Sponge and Dough Bread Making Process

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Executive Summary

This project was a collaboration between BRI Australia and the Leslie Research Centre, Department of Primary Industries and Fisheries Queensland. It represents a combined investment of the Grains Research and Development Corporation and the Value Added Wheat CRC.

The project undertook to establish the potential of Australian wheat to meet the Asian market requirement for sponge and dough bread manufacture. It was also seeking to develop methods to assist the selection of crossbreds with improved sponge and dough baking performance.

The initial phase of the project was the development of test baking methods that demonstrated similar sample ranking and discrimination to assessments made by Asian markets. A method was first established at BRI Australia on a one kilogram scale and this was subsequently scaled down to suit the Leslie Research Centre (200g). Following this BRI modified their method to use 300g. The scale of the methods was dictated by the selection of mixer. These methods were used to support the current project, the NWQTP, the northern region molecular marker program, and have been adapted for other wheat quality improvement programs.

A benchmarking exercise was completed using the test baking methods to compare flour samples milled from North American wheat classes and flour samples obtained from Asia. Apart from a sample of the wheat variety Kennedy, the North American samples consistently outclassed Australian Prime Hard wheat varieties. The most consistent observation made on the quality characteristics of the North American samples was their high dough strength and lower extensibility per unit protein than the Prime Hard varieties.

A group of 25 genotypes was selected at the Leslie Research Centre to be quality tested and baked using the purpose developed sponge and dough test baking method. Genotypes were grown at a total of three sites during 2000, 2001 and 2002. The results are reported in two sub sections with the 2000 work discussed in sub Section I and the 2001 and 2002 results in sub Section II. This structure was necessary since changes were made to the experimental procedure based on the 2000 harvest results. These included adjustments to the test baking method, extra quality tests performed and five additional genotypes included in the sample set.

The results indicated that dough strength was not a key factor for sponge and dough loaf volume as was earlier inferred following reviews of bread production methods and flour quality in Asia. The most important quality test correlated with sponge and dough loaf volume was flour swelling volume. This test was positively correlated with loaf volume with a relationship that was consistent across 2001 and 2002 and for both sites in 2002. Consequently the robustness of this relationship indicates the potential application of flour swelling volume as an indicator of sponge and dough loaf volume. These results were however considered to be limited by the sample set. Given the overall poor performance of Australian wheats for the sponge and dough process, it was difficult to represent an effective range of baking quality or indeed to have enough samples representing good baking quality. This means that the above outcomes concerning dough strength and starch properties need to be considered with some caution.

Analysis of glutenin and Wx-B1alleles suggested that these traits might also be important for sponge and dough bread quality. However, because some glutenin patterns are represented by only one or two genotypes, these results also need to be interpreted with caution. Additional work is required on specially selected samples to conclusively understand the importance of glutenin subunits for sponge and dough bread.

Consistent, large, sponge and dough loaf volumes were achieved by the Batavia/Pelsart crossbreeds, QT8753, QT10793 and QT10778. Hartog and Kennedy also performed well, however environment was demonstrated to be a significant factor. Some of these entries, in particular QT8753 have shown excellent yellow alkaline noodle sheet colour, indicating the potential for dual purpose wheats.

Bakery ingredients were demonstrated to have a significant effect on the sponge and dough baking process. Use of a commercial improver significantly increased the performance of Australian Prime Hard wheat and demonstrated that it can be used to produce bread of acceptable quality for the domestic Australian market using this process. However the combination of the correct wheat flour and ingredients provided a superior product that is required for the Asian market.

Overall, this work has demonstrated that Australia can produce wheats suitable for sponge and dough bread.

Recommendations

1. This project has demonstrated the potential for Australia to produce wheat for the sponge and dough market. It must now be demonstrated that this can be achieved consistently and sustainably. In particular, work needs to be completed to evaluate the economics of producing wheat with a protein content of 14% to determine if market premiums can support this.

2. When wheat varieties are released that can demonstrate consistent sponge and dough performance it is recommended that they are managed as a separate segregation. This is to ensure that they are delivered at the correct protein content and to ensure that they are not blended with other Prime Hard wheat varieties less suited to sponge and dough production as these will reduce the overall quality of the package. This segregation would be similar to the noodle wheat segregation in WA.

3. Technology packages need to be developed to support a sponge and dough segregation if it is developed. This would in particular seek to create ingredient combinations to optimise the performance of Australian wheat.

4. Further work is required to develop test methods to predict and better understand the flour quality requirements for sponge and dough performance. This requires more data on wheat and flour that demonstrates good baking quality. The present study was restricted by the sample range available. Ideally these samples would include wheat obtained from north America and wheat grown in Australia. It would be of considerable value to produce Australian wheat in the US environment and US wheat grown in Australia. This would assist in determining the influence of genotype and environment. It is also anticipated that other techniques such as molecular marker programs may be able to provide information on the wheat quality requirements for this process.

5. Further breeding with sponge and dough bread making as the target and supported by effective test baking methods is required to increase the range of wheats available to meet this market.

6. Research and development of a new alternative bread making process to better exploit Australian wheat in the Asian market is recommended. The research requires the technical development, milling protocols, processing and ingredients to produce bread suitable for the Asian market. The process must be suited for commercial

bread production and must deliver economic benefits to millers and bakers as this will attract them to adopt the Australian system. Such a system would need to exploit wheat from the Australian Hard class to achieve sustainable and economic protein targets. This approach has the potential to shift the market to suit Australian wheat rather than trying to take on North Americans at what they do best.

Background: The Sponge and Dough Wheat Market

Asia has widely adopted the sponge and dough method for the production of sandwich style bread. This method was originally adopted from the US but has now been adjusted to suit Asian tastes. Bread produced using the sponge and dough method accounts for over half the western style products manufactured in Asia. Countries using the sponge and dough bread making method include:

Japan
Sth Korea
Taiwan
China
Singapore
Malaysia and
Thailand

The total market for wheat used for sponge and dough production is estimated at six million tonnes. Bread consumption in Asia is still rising, particularly in China.

Sponge and dough production methods appear to be quite similar across Asia with approximately 60% of the flour mixed to form a soft sponge which is then fermented for 3.5 to 4 hours (Fig 1.).

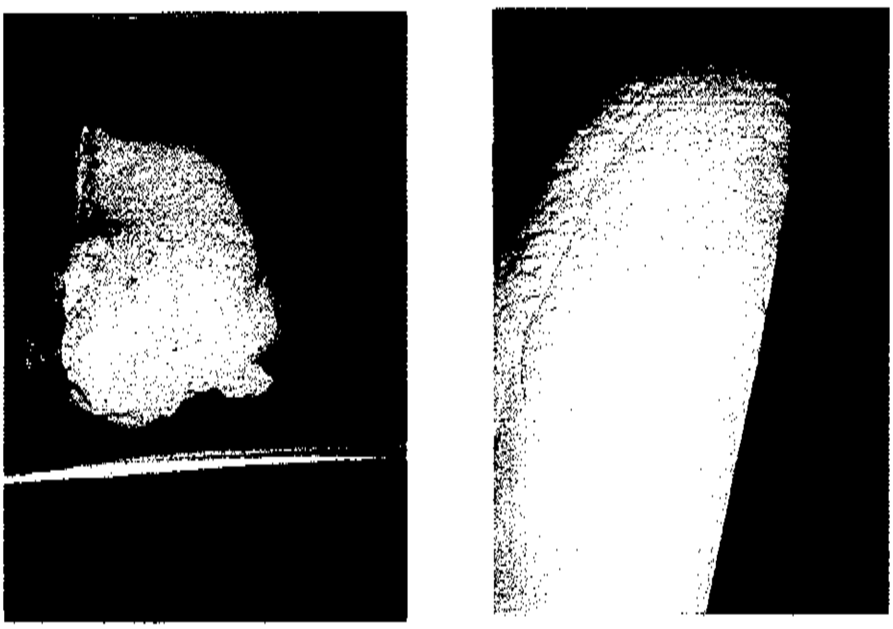


Fig 1. The sponge is placed in the trough to ferment from between 3.5 to 4 hours. The sponge rises to many times it's original volume.

The sponge and remaining ingredients are then mixed to form a dough. The rest of the process is similar to other bread making methods.

Consumers in Asia appear to prefer soft bread with a resilient bread crumb. A typical method of assessing the bread 24 hours after baking is to either fold a slice into two to ensure that the crumb does not rupture and to tear strips of the crumb away from a slice, where more resilient structures will allow long strips to be torn away intact. Other features of sponge and dough bread regularly referred to are the desirable flavour developed by the long fermentation period and an extended shelf life.

To produce bread suitable for this market, the Asian bread manufacturers tend to use flour with high protein content, between 12.5 and 13.5%, and high dough strength. Their formulations typically include high levels of sugar (5 to 12%) and fat (3-8%).

Australian Prime Hard wheat is not favoured for the production of this bread style and many of the markets are using high protein strong wheats from the US (Dark Northern Spring) and Canada (Canadian Western Red Spring). The customers describe the north American wheats as having greater dough strength and higher mixing tolerance.

The objectives of this project were to determine the potential of Australia to supply wheat for sponge and dough bread manufacturing and to identify the key wheat quality traits associated with wheat suited to the production of good sponge and dough bread.

Research

Research into the sponge and dough bread making system has been limited to studies in the US, Canada and Japan (Ikezoe and Tipples 1968; Kilborn et al 1981; Kilborn and Preston 1982; Preston and Kilbourn 1982; Shiiba *et al* 1990; Yamada and Preston 1994). Collectively, research has focussed on examining the baking system, without detailing the relative importance of specific wheat quality traits for good sponge and dough bread. Indeed, there seems to be a dearth of investigations relating current wheat quality test methods and baking performance in the sponge and dough system.

Existing test methods can be divided into 3 groups: (a) those that directly test grain quality; (b) those that test flour or dough quality; and, (c) those that test end product quality. Grain quality tests are easy to interpret as they focus on a single measure such as protein, moisture, or hardness. However, interpreting flour test results is more difficult since they broadly measure different physical responses of flour to interactions with water, heat, energy, and time. Unfortunately, the complex systems that physical dough tests are designed to measure are very different from that which occurs when processing flour into a consumable product such as noodles, biscuits, or bread. A study conducted in 1995 relating flour-water Farinograph and extensograph measurements to those conducted on a bread formula system (Oliver and Allen 1992) concluded that the two systems did not relate well. Because bread-baking systems are so complex and dynamic, the most unequivocal way to test a wheat's potential is to mill a sample, bake it, and measure the final loaf volume (cm^3). Crumb qualities such as structure and texture are also considered.

References

Ikezoe K and Tipples KH (1968) Farinograph studies on the effects of various oxidising agents on the sponge and dough system. Cereal Science Today 13, 327,328,330,358.

Kilborn RH, Nomura S and Preston KR (1981) Sponge- and dough bread. 1. Reduction of fermentation time and bromate requirement by incorporation of salt in the sponge. Cereal Chemistry 58, 508-512.

Oliver JR and Allen HM (1992) The prediction of bread baking performance using the farinograph and the extensograph. Journal of Cereal Science 15, 79-89.

Preston KR and Kilborn RH (1982) Sponge and dough bread: Effects of fermentation time, bromate and sponge salt upon the baking and physical dough properties of a Canadian red spring wheat. Journal of Food Science. 47, 1143-1148.

Shiiba K, Negishi Y, Okada K and Nagao S (1990) Chemical changes during sponge-dough fermentation. Cereal Chemistry 67, 350-355.

Yamada Y and Preston KR (1994) Sponge and dough bread: Effects of oxidants on bread and oven rise properties of a Canadian red spring wheat patent flour. Cereal Chemistry 71, 297-300.

Section 1

Evaluation of North American Wheat

Three samples of North American wheat were obtained for evaluation of wheat and flour properties with specific reference to their sponge and dough bread making quality. The samples were compared to the National Reference sample of Sunco (ex Project BRI90) and where possible a flour sample of the variety Kennedy.

The objective of this study was to provide a benchmark against which Australian wheat varieties could be compared for sponge and dough bread making quality. Whilst it is generally accepted in Asia that CWRS and DNS wheat grades have superior sponge and dough bread making performance, there is little data available actually comparing samples of these wheats under Australian test conditions.

Results
The milling quality of Sunco was superior to the three samples, when extraction rate was taken into consideration with ash and flour colour values. This observation was supported at 60% and straight run extraction. Sunco is recognized to be an excellent milling wheat and it would be valuable to compare these results to grade samples as the advantage of Australian wheat may not be as great as anticipated.

The North American samples had protein contents above 14% and also milled to produce higher starch damage. The result was higher water absorption than Sunco which is attractive to bakers.

The dough strength measurements including, farinograph dough development time and dough stability, and extensograph maximum resistance, indicate that the sample of Sunco was actually stronger than the North American samples. This was a surprising result as these wheats are often reported as having greater strength than Australian wheat. Again it would be good to compare a typical Prime Hard sample of 14% protein content.

The sponge and dough bread making performance of the North American wheat samples was clearly superior to the sample of Sunco. As there are many differences between the samples there is no single factor that can account for the superior baking.

Kennedy
A flour sample of the variety Kennedy which had been Pilot milled several years ago and stored at 4°C was also included in the comparison. Although this cannot be considered a direct comparison due to the different milling treatment and flour age, it has still provided an interesting opportunity. The sample of Kennedy had similar starch damage to the DNS and a higher ash content than the all the North American samples. This sample of Kennedy was also considerably stronger and had higher farinograph water absorption than the other samples tested. The sponge and dough performance of this Kennedy sample was equivalent to the North American samples tested. In previous comparisons to commercial flours from Asia this sample of Kennedy has compared very favourably. This particular sample of Kennedy is exceptionally strong and its baking performance is better than other samples of Kennedy tested.

In a comparison of 13 Prime Hard wheat types from the 2000 harvest, Kennedy produced the highest sponge and dough bread scores. However, with a similar sample set repeated in 2001, Kennedy although still performing well, was not in the top group. Other samples of Kennedy obtained opportunistically have performed well but have not achieved the high scores of the Pilot milled sample used in the current testing. Study of the protein composition of Kennedy has not revealed any stand out features that appears to be associated with its high baking quality.

Recommendations

1. Continue to collect North American wheat samples and evaluate them for flour quality and sponge and dough performance. A larger database is required to establish what the key differences between North American and Australian wheats determine superior baking performance.

2. Include Prime Hard wheat grade samples in future comparisons of sponge and dough performance. Whilst it is important to have individual variety samples, grade samples would provide an additional point of reference.

3. The wheat variety Kennedy has consistently shown superior baking performance. It can now be recommended as a parent for baking quality. However the actual traits contributing to this baking performance are not understood and further analysis of this variety in the context of other Australian wheats is required to better define the target quality.

4. Test baking is still the only effective method to determine the sponge and dough baking performance of wheat varieties. Further work is required to identify key traits that can be used to predict performance in earlier generations and at less cost than baking tests.

Samples

The following wheat samples were obtained from North America for evaluation in the sponge and dough bread making process.

	Wheat protein content (%)	
1. Canadian Western Red Spring (CWRS)	15	Canada
2. Dark Northern Spring (DNS) 14	14.4	US
3. Dark Northern Spring (DNS) 15	15.1	US

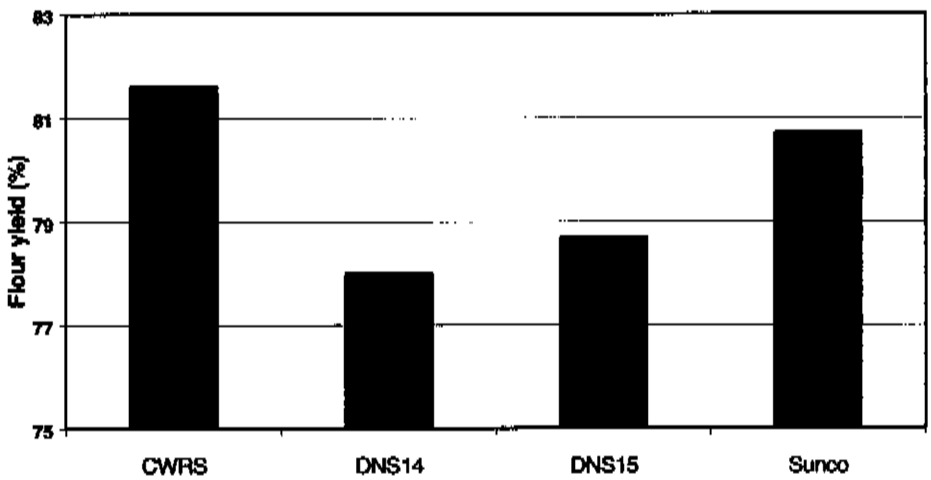
These samples were compared to the national reference sample of Sunco (wheat protein content of 13.2%). However, it is also possible to compare the data to other NWQTP samples as the testing and data are in the same format. Flour produced from the above samples is also compared to a flour sample of the wheat variety Kennedy. This sample is from a BRI Pilot Milling of Kennedy and is not directly comparable to the other samples. This sample has produced excellent baking results on the sponge and dough system. The sample has now been stored for over two years. Although this has been at 4°C, the sample has shown some increase in dough strength and water absorption.

Sample size was limited for the North American wheats, which were milled to a straight run extraction to measure milling performance with adequate flour for most quality tests. This straight run extraction data allows direct comparison with the NWQTP. A sample of each grade was also milled to 60% extraction. This sample was large enough for more extensive testing which included extensographs and sponge and dough baking. The following graphs compare the key features of these samples and detailed test results are presented on pages 11 to 13.

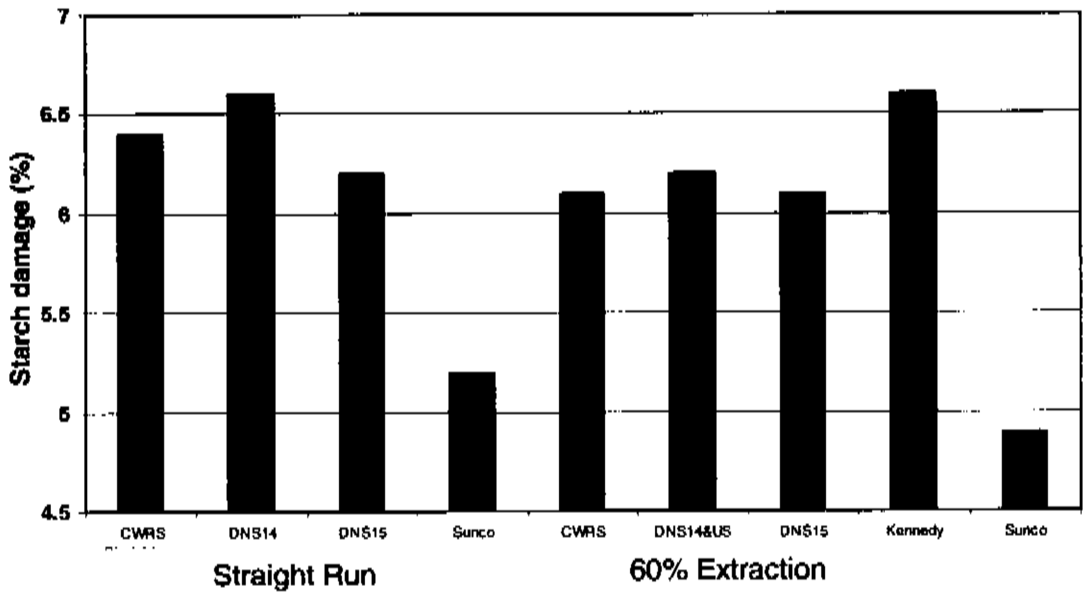
Results

Flour yield

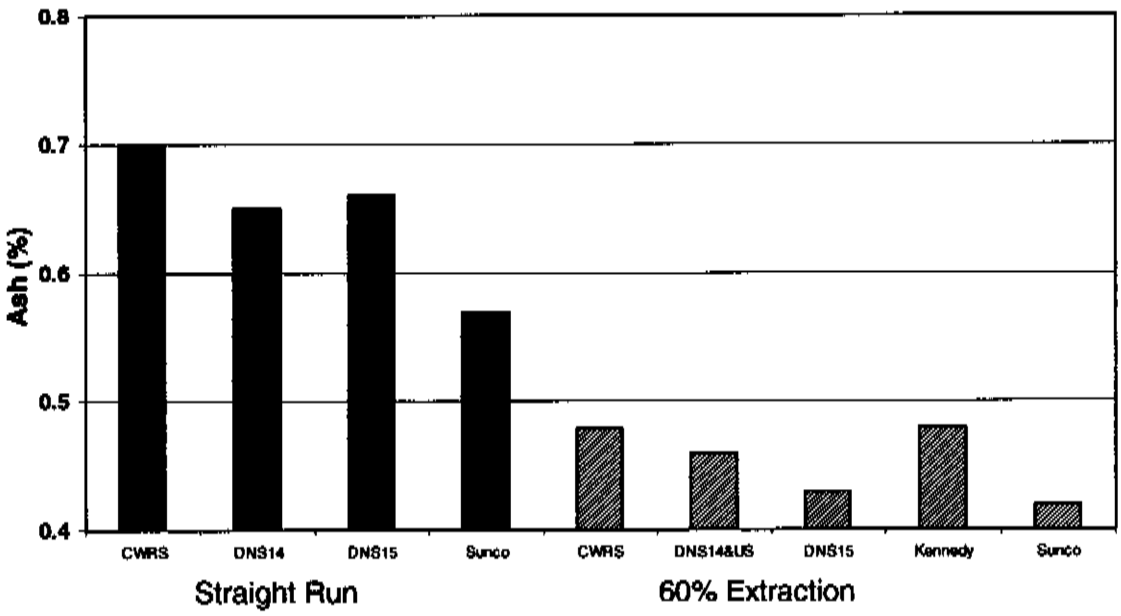
The sample of CWRS achieved the highest straight run flour yield, this result is considered very high. To put the results in context, a sample of Sunco submitted to the NWQTP from the 2001 season, achieved an extraction rate of 77.5, below that of the present DNS 14 sample.



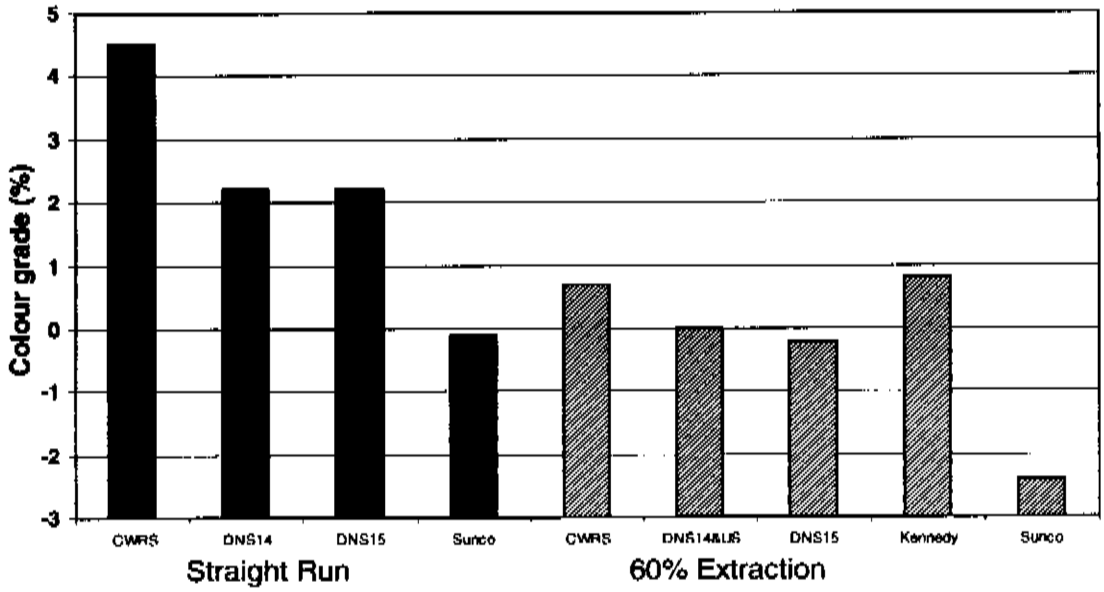
Starch Damage
The sample of Sunco produced lower starch damage than the north American samples at both straight run and 60% extractions. The Sunco sample had the lowest PSI of the samples. The starch damage values for these DNS samples are similar to what we would expect for Hartog. Kennedy had a similar level of starch damage to DNS14.



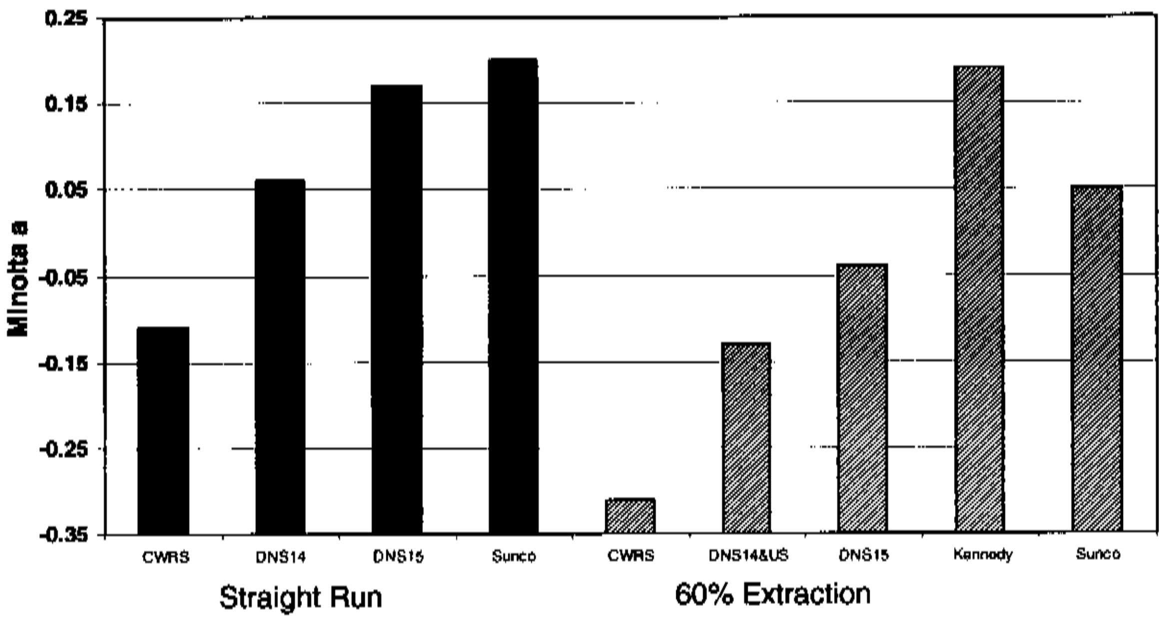
Ash
The straight run ash values were clearly higher than for the 60% extraction samples. At both extraction rates the CWRS had the highest ash and Sunco the lowest. Considering the ash values and extraction rates this sample of Sunco clearly has superior milling quality.



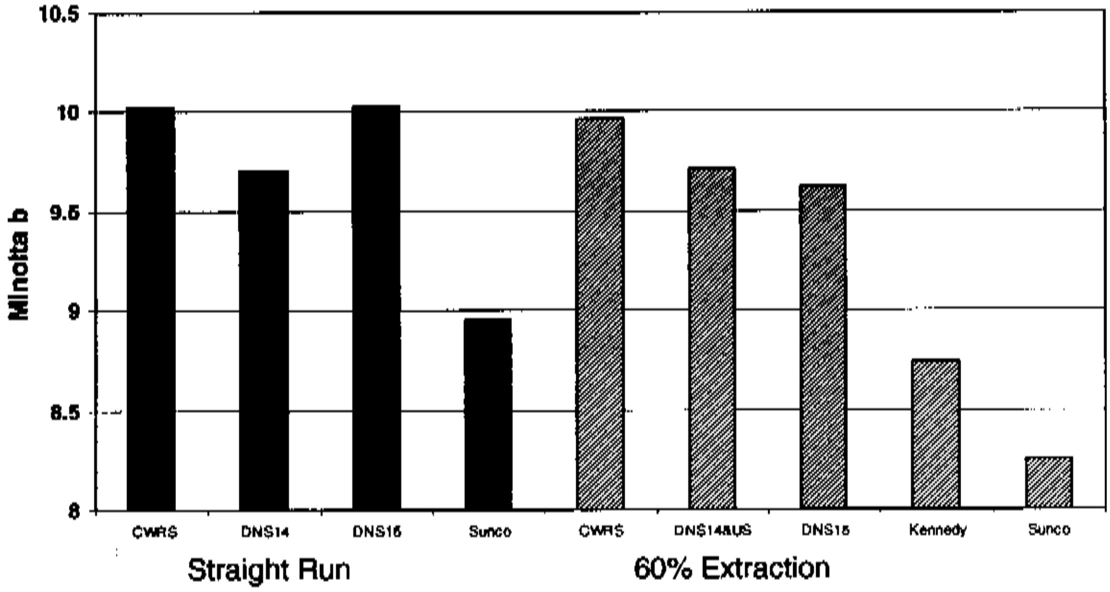
Colour grade:
The Sunco colour grade at a straight run extraction was better than or similar to the North American samples at 60% extraction. Again the superior colour grade of the Sunco sample reflects better milling performance. At straight run extraction, Hartog would be expected to achieve a colour grade of 0.5 to 1.0 still considerably lower than the north American samples.



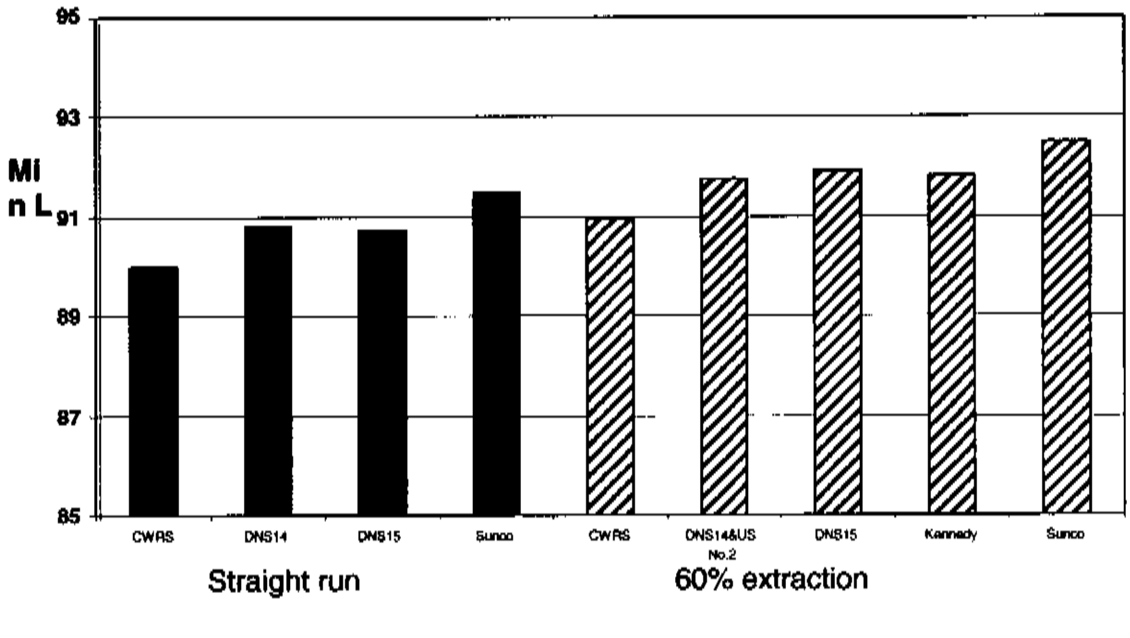
Flour Colour: Minolta a*:
We do not usually comment on the Minolta a values, however, although the differences between the samples are small, the trend is interesting with Sunco appearing to have the highest red values at both extractions, a result which is difficult to interpret given that the north American wheats were red grained.



Flour Colour: Minolta b*:
Sunco produced a less yellow flour than the north American samples, as did the Kennedy. This would be considered an advantage for bread making.

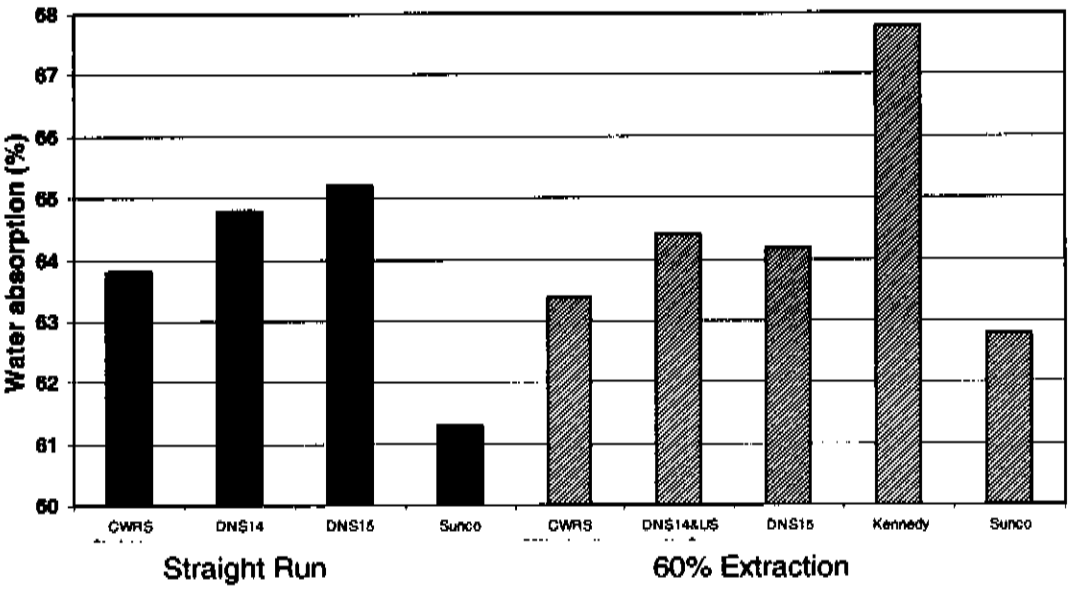


Flour colour: Minolta L*
Sunco produced the brightest flour at both extraction rates. CWRS has the least bright flour at both extraction rates.



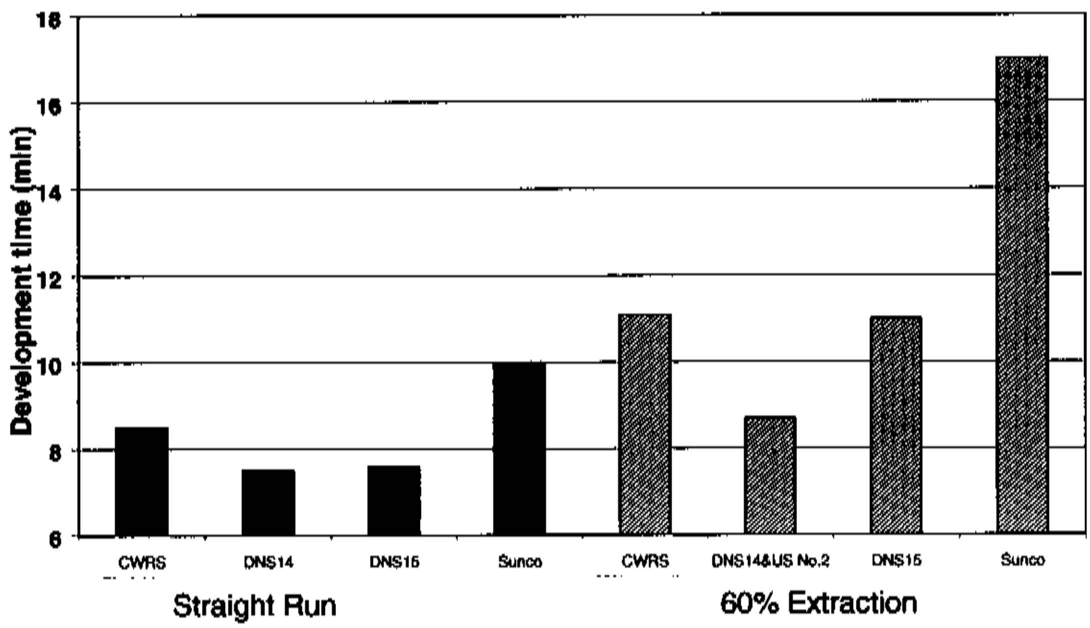
Farinograph Water Absorption:

Sunco had a significantly lower Farinograph water absorption than the north American samples. The value measured for this sample of Kennedy is particularly high.



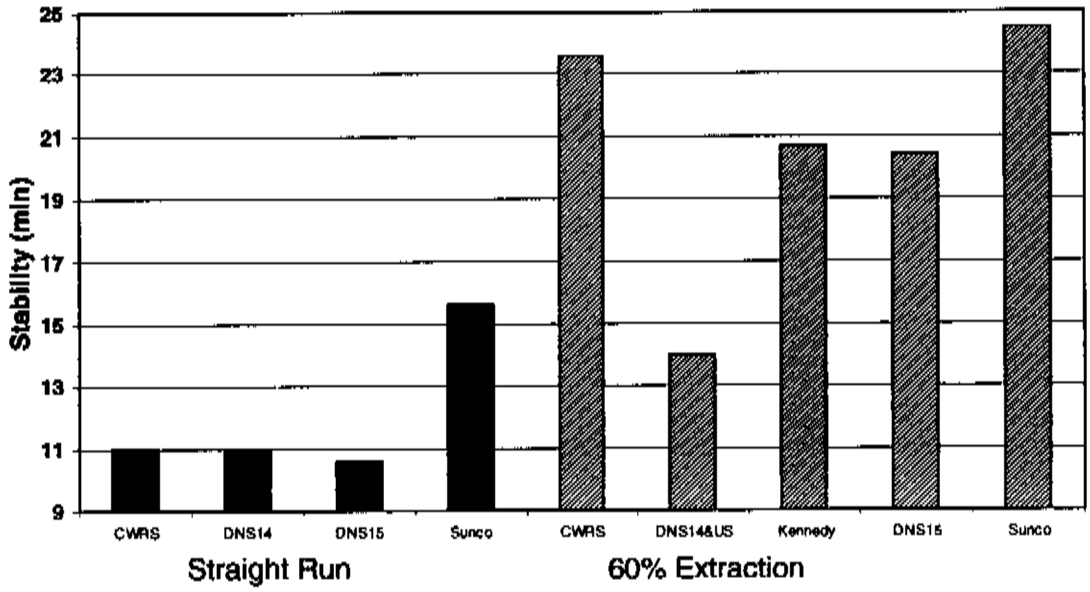
Farinograph Development Time

Farinograph development times were higher for the 60% extraction samples. At each extraction rate Sunco had the highest development time.



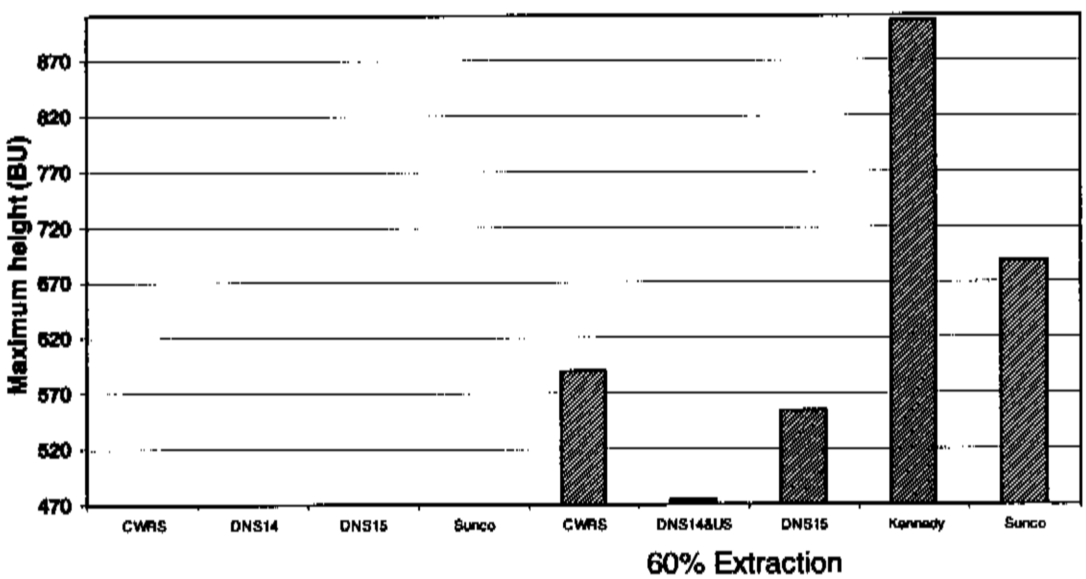
Farinograph Dough Stability

Dough stability values were significantly higher at the 60% extraction rate. At both extraction rates Sunco had the highest dough stability values.



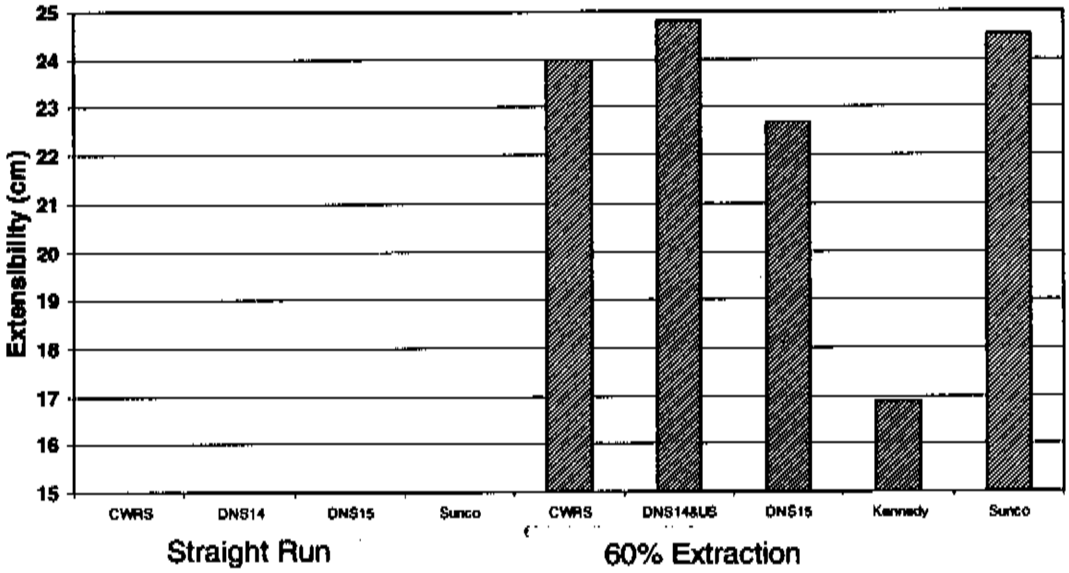
Extensograph Rmax:

Due to insufficient sample size we did not complete extensographs on the straight run flour samples. This test was carried out on the 60% extraction samples as these were used for baking. The Sunco sample had higher dough strength than the north American samples. This was consistent with the dough strength indicators of Farinograph stability and development time. The sample of Kennedy was extremely strong.



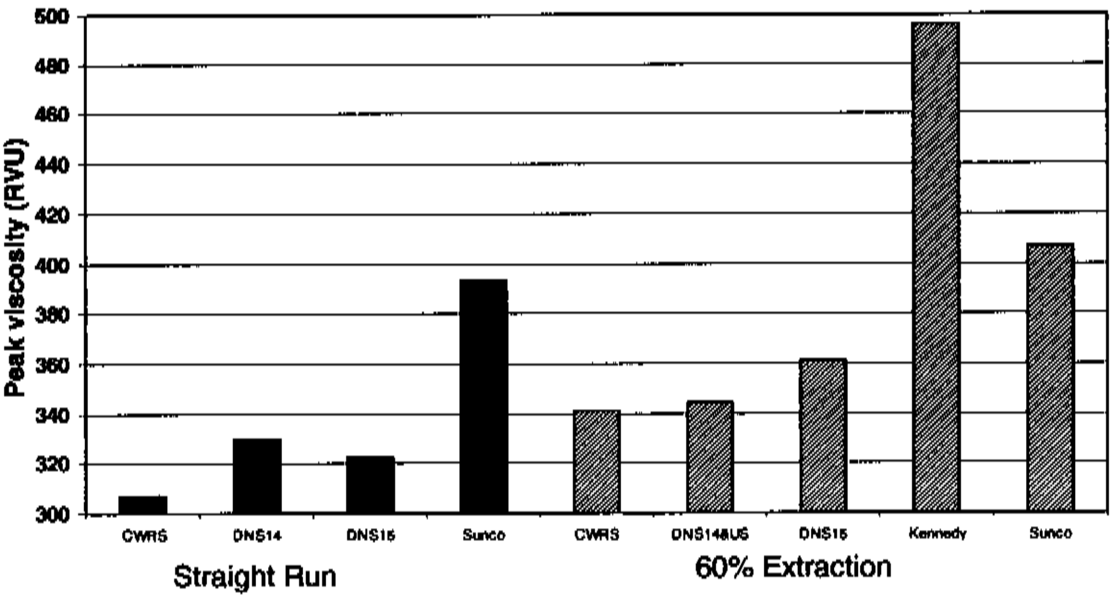
Extensograph extensibility

At the highest protein content the DNS 15 had the lowest extensibility. Sunco clearly had the highest extensibility per unit of protein.



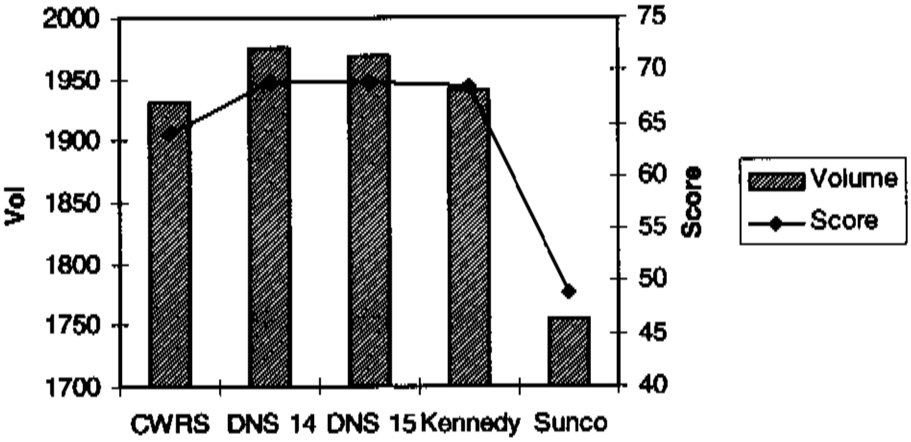
RVA peak viscosity

The 60% extraction flours had marginally higher RVA peak viscosity. Sunco had higher RVA viscosity than the north American samples, yet by Australian standards Sunco is not considered to have high starch pasting properties. Kennedy had significantly higher RVA peak viscosity.

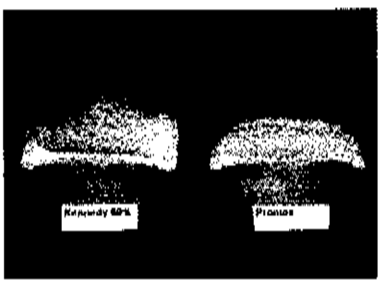


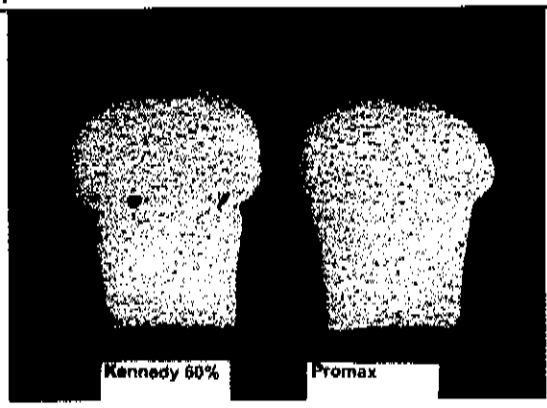
Sponge and Dough Baking

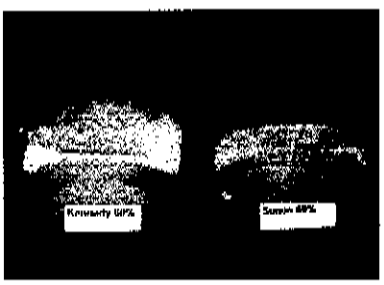
The north American samples produced significantly higher bake scores and loaf volumes compared to this sample of Sunco. The sample of Kennedy was marginally lower than the DNS samples and similar to the CWRS.

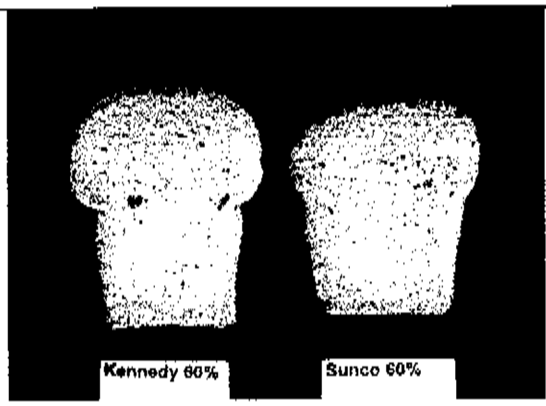


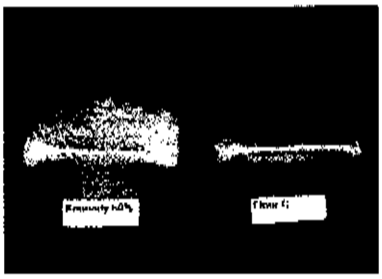
Photographs
Photographs of the bread are provided in the following pages. Note: Flours C and G were commercial flours obtained from Singapore.

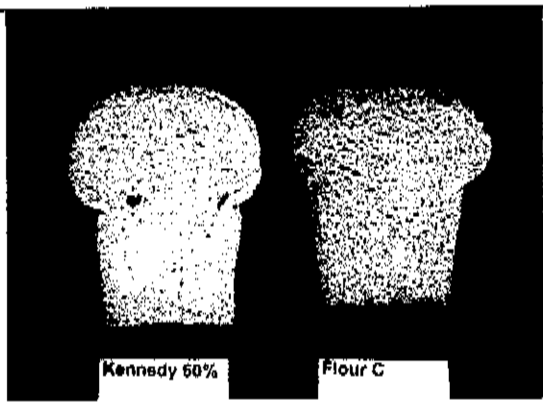


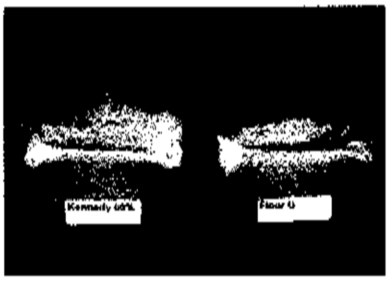


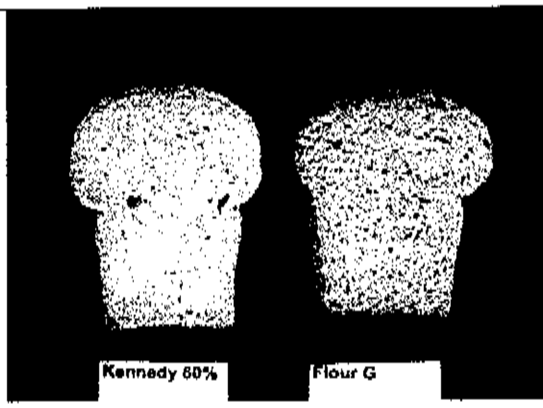


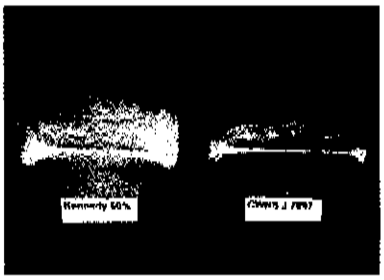


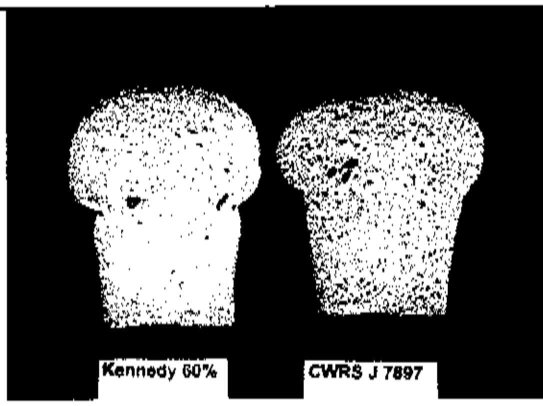


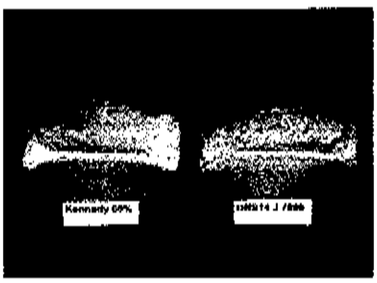

Kennedy 60%
Flour C

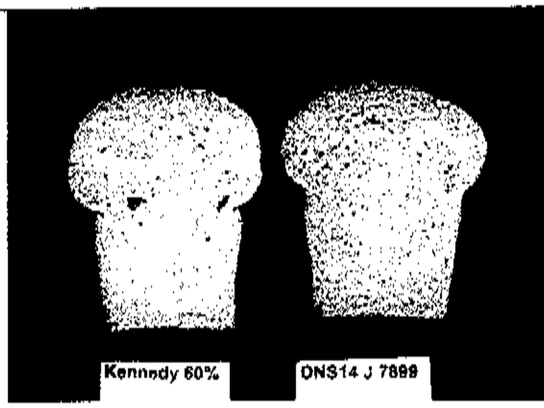


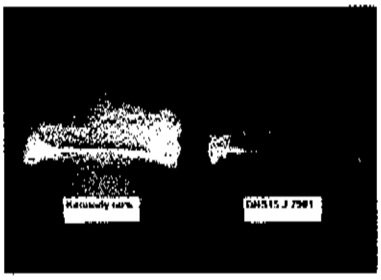

Kennedy 60%
Flour G

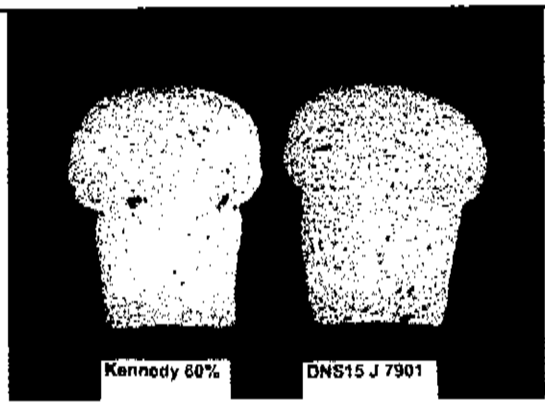


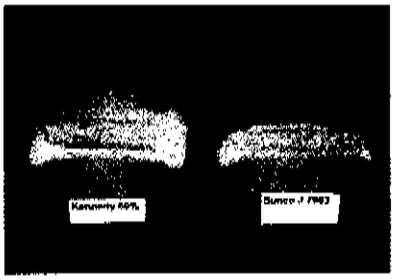

Kennedy 60%
CWRS J 7897

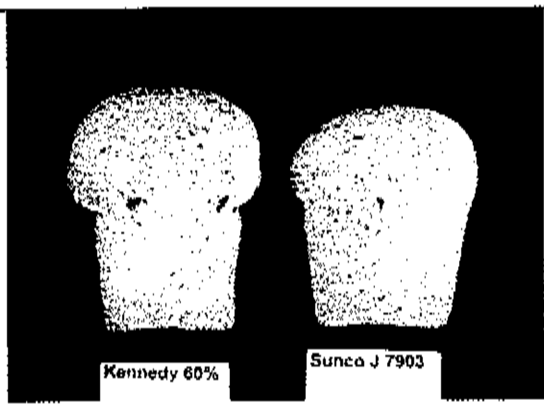



Kennedy 60%
DNS14 J 7899




Kennedy 60%
DNS15 J 7901




Kennedy 60%
Sunco J 7903

North American Wheats - Sponge & dough process- Straight run flours

	CWRS J7896	DNS14 J7898	DNS15 J7900	Sunco J7902
Wheat				
Test weight (kg/hl)	73.5	82.0	81.1	82.9
Thousand kernel weight (g)	35.2	33.3	31.5	32.8
Grain hardness (PSI)	15	12	13	16
Protein (%, N x 5.7)	15	14.4	15.1	13.2
SKCS (Hardness)	68.5	71.5	69.2	
Flour extraction (%)	81.6	78.0	78.7	80.7
Flour				
Protein (%, N x 5.7) 14% moisture basis	14.3	13.5	14.3	12.8
Starch damage (%)	6.4	6.6	6.2	5.2
Ash (%) 14% moisture basis	0.70	0.65	0.66	0.57
Colour grade	4.5	2.2	2.2	-0.1
Minolta - L	89.98	90.81	90.73	91.49
- a	-0.11	0.06	0.17	0.2
- b	10.03	9.70	10.03	8.95
- L-b	79.95	81.11	80.7	82.54
Farinograph - water absorption (%)	63.8	64.8	65.2	61.3
- development time (min)	8.5	7.5	7.6	10.0
- stability (min)	11.0	11.0	10.6	15.6
Extensograph - extensibility (cm)	N/A	N/A	N/A	N/A
- maximum height (BU)	N/A	N/A	N/A	N/A
RVA -peak viscosity (RVU)	307	330	323	393

Comments

The test weight of the CWRS was quite low, however the TKW was the highest of the samples with DNS 15 displaying the smallest grain size. Sunco was the softest and DNS 14 the hardest sample, this was also reflected in the starch damage results. The ash content of Sunco was significantly lower than for the CWRS and DNS samples, this was also reflected in the colour grade. On the Minolta, Sunco produced brighter and whiter flour. Sunco had the lowest water absorption, and highest development time and stability.

North American Wheats - Sponge & dough process- 60% extraction flours

	CWRS J7897	DNS14 J7899	DNS15 J7901	Sunco J7903
Wheat				
Test weight (kg/hl)	73.5	82.3	81.1	82.9
Thousand kernel weight (g)	35.2	32.3	31.5	32.8
Grain hardness (PSI)	15	13	13	16
Protein (%, N x 5.7)	15.0	14.4	15.1	13.2
SKCS (Hardness	68.5	71.5	69.9	
Flour extraction (%)	60	60	60	60
Flour				
Protein (%, N x 5.7) 14% moisture basis	14.1	13.1	13.8	12.0
Starch damage (%)	6.1	6.2	6.1	4.9
Ash (%) 14% moisture basis	0.48	0.46	0.43	0.42
Colour grade	0.7	0.0	-0.2	-2.4
Minolta - L	90.96	91.75	91.89	92.48
- a	-0.31	-0.13	-0.04	0.05
- b	9.96	9.71	9.62	8.25
- L-b	81.00	82.04	82.29	84.23
Farinograph - water absorption (%)	63.4	64.4	64.2	62.8
- development time (min)	11.1	8.7	11.0	17.0
- stability (min)	23.6	14.0	20.4	24.5
Extensograph - extensibility (cm)	24.0	24.8	22.7	24.5
- maximum height (BU)	590	475	555	690
RVA -peak viscosity (RVU)	341	344	361	407

Comments

The protein content of the CWRS and DNS samples was at least 1.2% higher than for Sunco. The grain was harder and at an identical extraction rate CWRS had the highest ash. The CWRS and DNS had significantly higher colour grade values than the Sunco sample. Colour measured on the Minolta indicated that the Sunco sample was brighter and whiter.

The sample of Sunco had the lowest water absorption but the longest development time. It also had the highest dough strength. Note that when milled to straight run extraction the Sunco Rmax was 515BU.

North American Wheats - Sponge & dough process - 60% extraction flours

	CWRS	DNS14 & US No. 2	DNS15	Kennedy	Sunco
	J7897	J7899	J7901		J7903
Sponge and Dough bread					
Water addition (%)	160	160	160	160	120
Mixing time (sec)	180	220	220	270	240
Sponge height (cm)	8.5	10.5	10.5	6.5	8
Proof time (min)	45	47	46	52	52
Average volume (cc)	1931	1975	1969	1942	1756
Total score /100	64	69	69	69	49

Comments

The baking results of the DNS samples were clearly superior and these were considered very good scores. This sample of Kennedy has consistently produced sponge and dough bread of a very high standard.

Of interest in these results is the sponge height, which is the height of the sponge after fermentation. The DNS samples produce a high sponge height, which appears to be consistent with the better "flow or softness" of these doughs. We also note that both Australian samples required longer proof times. This could be due to different fermentation rates or the ease of dough expansion in the prover. It is considered that the Sunco and Kennedy samples have very strong doughs that might restrict expansion and therefore require a longer proof. This may also be consistent with the lower sponge height values. What this indicates is that strength alone is not enough for good sponge and dough performance. There is also a dough flow property that is not expressed by extensibility, as the DNS samples were no more extensible than the Sunco (although clearly more extensible than Kennnedy). It is possible that it is a balance between strength and extensibility or there is another measure/factor we are not effectively measuring.

Further investigation is required and additional North American samples will assist.

Section 2

Wheat Quality Evaluation for the Sponge and Dough Process. Including Queensland Department of Primary Industries Field Trials, Wheat and Flour Testing

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2.1. Introduction

This section of the study reports on an investigation to:

- Identify the key wheat quality characteristics required for bread manufacture by the sponge and dough process in Asia.
- Identify Australian wheat cultivars that have some or all of the quality requirements for sponge and dough bread.
- Determine the feasibility of combining yellow alkaline noodle and sponge and dough making quality in one wheat variety.

2.2. Preliminary study in 2000

Surveys of bread production methods and flour quality in Asia indicated dough strength was important for good quality sponge and dough bread. Consequently a range of genotypes where chosen that are known to produce strong dough properties and to provide a range of quality attributes. Accordingly, seven cultivars and 18 advanced breeding lines were used in the trials conducted in 2000, (Table1).

Table 1. Genotypes selected to explore characteristics required for sponge and dough bread.

Genotype	Pedigree
Banks	PWTH/Condor sibling//2*Condor
Baxter	Inia 66/Gamut//Cook/4*Jupeteco/3/Lerma Rojo 64/Sonora 64A//Timgalen sibling
Chara	Cook*2/Millewa//TM56/Pavon'S'/Condor
Hartog	Vicam 71//Ciano'S'/Siete Cerrois/3/Kalyansona/Bluebird
Kennedy	Veery#5/Hartog
Kukri	DRP((FNK58xN10B/Gb55)NAI60)/(TOB-CNO'S'xTOB8156/CALxBb-CNO)/2/MDN/6*RAC820
Lang	QT3765/Sunco
QT9616	GS50A/3*Cunningham//Janz
QT9274	Batavia/2*Hartog
QT9276	Batavia/2*Hartog
QT9293	27IBWSN198
QT9346	TRANS/3*Janz/Cunningham
QT9347	TRANS/3*Janz/Cunningham
QT9673	TRANS/3*Janz/Cunningham
QT9683	QT2327/Cook//QT2804
QT9900	Vulcan/2*Janz
QT9933	Vulcan/2*Janz
QT9913	Janz/2*Opata
QT9916	Janz/2*Opata
QT9919	QT4369/2*QT4293
QT10181	Miskle/Janz
QT10183	Miskle/Janz
QT10757	2*Batavia/PelsartDH
QT10778	2*Batavia/PelsartDH
QT10793	2*Batavia/PelsartDH

Trials were grown at Roma and Billa Billa in southwestern Queensland during the winter of 2000. Plots were arranged in 2 replicates of a latinised row-column design at each site. After harvest field replicates were combined in order to produce sufficient quantities of sample for laboratory testing. Laboratory tests were carried out following the methodology in Section 3.1.3 of the report.

Due to the combination of replicate samples and lack of duplication and experimental design at the laboratory phase, the 2000 results were treated as an observational study. Preliminary results on grain, flour, dough and end product relationships were examined, and used to modify the study for 2001-2002.

2.2.1 Results

All of the 25 genotypes from both the Roma and Billa Billa sites, achieved grain protein greater than 12%, falling number above 300 s, and test weight over 70 kg/hL and so were accepted for further quality analysis and test baking. Table 2 provides a summary of all the quality test results.

Table 2. Quality test result summary for 25 genotypes grown at Roma and Billa Billa, 2000.

Quality parameter	Abbreviation	Mean	SD	Minimum	Maximum
Loaf volume (cm^3)	LV	875	45	750	945
NIR grain protein (%)	GP	14	2	12	18
Falling number (s)	FN	410	34	352	485
Test weight (kg/hL)	TW	78	4	71	84
Minolta flour colour (L-b)	FC	80	2	77	83
Max. Extensograph extensibility (cm)	E1	25	2	18	27
Max. Extensograph resistance (BU)	E2	455	63	260	626
Resistograph breaking point (min)	R1	11	4	3	20
Resistograph weakening angle (deg)	R2	118	15	68	140
Farinograph water absorption (%)	F1	64	3	58	71
Farinograph dough development (min)	F2	9	2	5	14

The 200 g sponge and dough test baking method was effective in discriminating between the cultivars and lines used in this study. The best performers over both sites were Kennedy, Hartog, QT10778, Banks and QT10757 followed by QT9274, Chara, and QT9933.

A correlation matrix between all measured traits is shown in Table 3. Two traits are significantly correlated with loaf volume, but only explain a small percentage of the variation in this trait. The presence of significant correlations between other quality test results highlights the complex nature of inter-trait relationships.

Table 3. Correlations between all measured traits in the 2000 quality tests.

	LV	E1	E2	R1	R2	F1	F2	GP	FN	FC	TW
LV	1										
E1	0.15	1									
E2	**0.33**	0.12	1								
R1	-0.10	**0.32**	**0.60**	1							
R2	0.05	**0.49**	**0.56**	**0.86**	1						
F1	-0.21	0.08	-0.23	-0.02	0.02	1					
F2	-0.11	**0.32**	**0.54**	**0.76**	**0.73**	-0.01	1				
GP	**-0.39**	**0.33**	0.04	**0.44**	**0.43**	**0.69**	**0.34**	1			
FN	-0.24	**0.40**	0.22	**0.37**	**0.44**	**0.51**	**0.33**	**0.78**	1		
FC	-0.13	0.05	-0.04	-0.02	0.06	**-0.52**	0.12	**-0.40**	**-0.28**	1	
TW	0.07	-0.26	-0.12	**-0.36**	**-0.32**	**-0.72**	-0.23	**-0.80**	**-0.71**	**0.58**	1

Significant correlations in bold type exceed 0.27 (P=0.05) and 0.35 (P=0.01).
[a] LV-loaf volume (cm^3), E1-extensograph extensibility (cm), E2-extensograph resistance (BU), R1-resistograph breaking point (min), R2-resistograph weakening angle (deg), F1-farinograph water absorption (%), F2-farinograph dough development time (min), GP-NIR grain protein (%), FN-falling number (sec), TW-grain test weight (kg/hL)

To effectively summarise the information across multiple correlated traits a principal components analysis was performed. This analysis produced two independent axes that accounted for 97% of the variation in the data. The results are summarised in a biplot (Fig 1), where the genotypes at each site are plotted on the new principal component axes and overlaid with the relationship between the quality traits, indicated by the vectors.

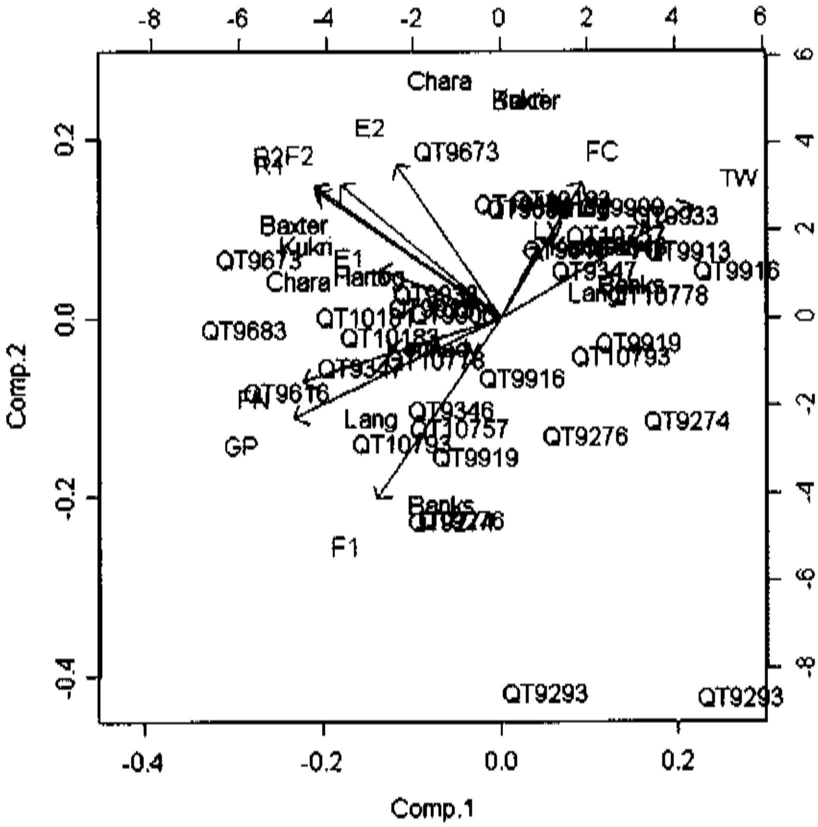

Fig 1. A biplot of the 25 genotypes from Roma and Billa Billa, 2000, and measured quality traits. (Trait names are abbreviated as in Table 2.)

The results indicated that there is no single measured quality trait contributing to the sponge and dough loaf volumes. This could be due to; non-optimal experimental design, insensitivity of the baking method or inherent limitations of the quality tests used. To overcome these, in future work:

- Field plot size should be doubled, and a duplicated, designed experiment be adopted at the laboratory phase of testing.
- Dough mixing time in the test baking method should be optimised.
- Measurement of milling yield, grain hardness, flour swelling volume, the Wx-B1 gene present, glutenin alleles and mixograph parameters should be incorporated.

2.3. 2001 and 2002 Harvests

2.3.1. Materials and methods

3.1.1: Field trials

The set of 25 genotypes employed for 2000 harvest (Table 1) was expanded to 30 by including the extra cultivar and advanced breeding lines as shown in Table 4.

Table 4. Five additional genotypes were included in the 2001 and 2002 harvest trial.

Genotype	Parentage
Babbler	Janz/Lark
QT8974	Cunningham/Sunco
QT8620	GS50A/3*Cunningham//Janz
QT8750 (EGA Hume)	2*Batavia/PelsartDH
QT8753	2*Batavia/PelsartDH

Trials were grown at Roma in 2001 and Roma and Biloela in Central Queensland in 2002 as described in Table 5.

Table 5. Field trial events.

	Roma 2001	Roma 2002	Biloela 2002
Urea (kg/ha)	120	80	150
Starter Z (kg/ha)	40	40	40
Pre-plant irrigation (mm)	75	75	75
Planting date	May 31st	June 24th	May 24th
In-crop rainfall (mm)	81- Jul 21 – Sep 37 – Oct	125 – Aug	122 - Aug
Harvest date	Oct 31st	Nov 1st	Oct 20th

3.1.2: Experimental design

The wheat quality data in this trial was obtained from a multi-phase process. The first phase involved the field trial where genotypes were grown in plots. Grain was harvested from these plots and put through a milling process. Flour was then tested in the laboratory. The quality traits therefore contain variation from each of the field, milling and laboratory processes (Smith *et al* 2001). In addition, the field trials were grown across a number of environments (2001 Roma, 2002 Biloela and 2002 Roma) so genotype by environment interaction needed to be considered. Consequently, at each phase of the experimental process, replication has been incorporated.

3.1.2.1: 2001 harvest

The 2001 study was based on a two-phase design. The experiment consisted of 30 genotypes grown at one location (Roma) in a replicated trial. The trial was planted as a latinised row-column design, in a two dimensional array defined by rows and columns in the field. Grain samples from each field plot were split into two duplicate samples and then processed in the mill and laboratory. Plots were allocated to positions within the laboratory process using an incomplete block design, with blocks being test day. Through this field and laboratory duplication, the set of 30 genotypes was expanded to include a total of 90 samples.

3.1.2.2: 2002 harvest

The 2002 study was based on a three-phase design. The field phase involved a trial of 30 genotypes at two locations, Roma and Biloela, each planted as a latinised row-column design with two replicates. Once again, duplicate grain samples were taken from each field plot and allocated to the milling process using an incomplete block design for each site, with milling day forming the incomplete blocks. Duplicate samples of flour were taken from these milled samples and allocated to the third phase of testing in the laboratory, while whole grain measurements such as milling yield, protein and falling number were measured at the second phase. Consequently the set of 30 genotypes at 2 sites was expanded to include a total of 300 test samples.

3.1.3: Measurement of quality traits

Samples were cleaned through a Carter Dockage Tester (Carter Day International, Minneapolis, US) over a 2mm sieve to retain the main grain fraction. GAC 2100 Agri meter moisture, 1000 kernel weight and NIR protein was performed on whole grain samples. Particle size index and falling number was performed on samples according to Approved Method 55-30 (AACC 2000) and ICC method 107 (1997) respectively. Samples were conditioned to 15% moisture prior to milling in a randomised order through a Buhler, MLU-202, pneumatic mill by Approved Method 26-21A (AACC 2000). Flour colour was measured using the Minolta colour meter according to Method 09-02 (RACI 1995).

Water absorption (%) and dough development time (min) were determined using the 50g Farinograph (Brabender Duisburg, Germany) as outlined in Method 06-02 (RACI 1995). Tests were repeated if the mean consistency at maximum development was not within 500 BU +/- 30 units.

Maximum extensibility (cm) and maximum resistance (BU) at 45 min were determined from two dough pieces of 150 g each from one mix as outlined in Method 06-01 (RACI 1995), using the farinograph-resistograph and extensograph, (Brabender Duisburg, Germany). Results from the two dough pieces were accepted provided they agreed to within 15% of their mean value.

The ten-gram mixograph was employed for 2001 and 2002 harvest samples, according to Approved Method 54-40A (AACC 2000). The trace measurement, 'range of stability' was employed after a pilot study (n=90) indicated this measurement provided the only genetic correlation with sponge and dough loaf volume (Table 6). Range of stability is defined as the distance between the two points where the line drawn through the curve peak parallel to the base cuts the edges of the curve (Harris 1943).

Table 6. Range of stability (cm) provided a significant correlation with sponge and dough loaf volume in a pilot study of mixograph parameters (* significant at $P< 0.05$)

Mixograph trace measurement	Genetic correlation with loaf volume (cm^3)
Time to maximum height (min)	- 0.182
Maximum height of curve centre (cm)	- 0.061
Angle between ascending and descending portions of curve at peak (deg)	0.026
Range of stability (cm)	0.517*
Maximum bandwidth at peak (cm)	0.187

The sponge and dough baking test was altered from that employed for the 2000 harvest study. The main changes were to optimise the dough mixing time and to prove loaves for 60 minutes instead of to a set height.

A water-jacketed GRL-200 pin mixer (Muzeen and Blythe Ltd, Manitoba, Canada) was used for all mixing operations. The sponge component consisted of: flour 140 g, yeast 4 g, water 84 mL, bread improvers (calcium hydrogen orthophosphate 0.5 g, ammonium sulphate 0.06 g, malt flour 0.5 g) 1.62 g, mixed for 2 min at 60 rpm. Added water and water bath temperatures were monitored and adjusted to achieve a finished sponge temperature of 26°C +/- 0.5°C. The sponge was fermented in a sealed container at 28°C for 3 h and 55 min. The dough was formed with; flour 60 g, sugar 10 g, fat 6 g, salt 4 g, water variable, sponge total, mixed at 60 rpm until optimal dough development was observed (usually after between 2 and 6 min). Water temperatures were adjusted to achieve a finished dough temperature of 28°C +/- 0.5°C. Water addition was calculated as:

Total dough water mL = (Farinograph water absorption % - 6) x 2 – 84 mL

The mixed dough was rested for 20 min, divided into two 160 g dough pieces, moulded in a mono universal moulder (D. Ayres, Jones and Co., Ltd. Swansea, Great Britain), rested for 10 min, moulded again, placed in an oiled 550 cm^3 loaf tin, then proofed at 39°C and 80% rh for 60 min. Loaves were baked for 15min at 200°C, removed from the tin, cooled at room temperature and the volume measured in a seed displacement volumeter. Assessment and scoring for external appearance, oven spring and crumb texture, structure and colour was completed between 18 and 24 h following baking. Test baking results reported are the average loaf volume of two dough pieces, from a single batch of dough divided prior to moulding. For this work the scores were not included in the total analysis of results due to their qualitative nature and strong correlation with loaf volume.

A considerable amount of time was spent attempting to minimise sources of variation in the test baking method. Experiments with improver formulations, yeast storage and handling, mixing operations, moulder settings, cabinet temperatures, baking tin dimensions, process timing and general dough handling techniques were all examined carefully to eliminate possible sources of variation in the method. Air bubble formation during moulding is an example of variation intrinsic to the method that is difficult to eliminate. A critical factor for repeatability of the method is timing. Each batch must be started at exactly equal intervals, so that time spent at each stage of the procedure is identical for each sample. Nonetheless, significant baking day effects were found in the analysis and adjusted for in the statistical model.

The method was able to discriminate between flours of different quality used in Asian bread production (Fig 2). With assistance from AWB, three grades of flour, Premium, Standard and All-purpose, were obtained from FFM Berhard mill in Malaysia and evaluated using the above baking method. Analytical data for these samples is listed in Appendix 1.

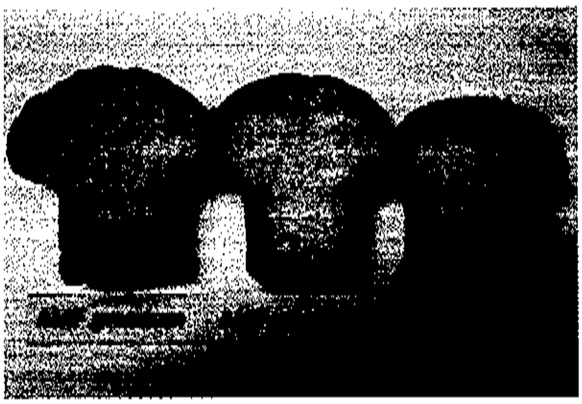

Fig 2. Loaf volumes for Premium, Standard and All-Purpose grades of Asian milled flour (AMF) were 860cm^3, 805cm^3 and 680cm^3 respectively.

3.1.4: Statistical analysis

The extended mixed model approach of Smith *et al* (2001) for multi phase designs was used for analysis. Variance parameters were estimated using residual maximum likelihood (REML) (Patterson and Thompson 1971). The statistical model was fitted using samm (Butler *et al* 2004), the S-Plus suite of functions for the statistical software program ASREML (Gilmour *et al* 2001). Best linear unbiased predictors (BLUPs) for the random genotype effects were predicted for each quality trait. Biplots (Gabriel 1971) were constructed after performing principal components analysis on each of these sets of predictions. Genetic correlations were estimated between sites for each trait and the adequacy of a common correlation between sites or the need for separate correlations tested. Where correlations between pairs of sites were high and similar, a common genotype effect for the trait was predicted across sites. A final biplot encompassing both 2001 and 2002 work was constructed after principal components analysis on the resulting combined and/or separate data. Genetic correlations were also calculated between loaf volume and all other traits for each site/year. The effect of glutenins on loaf volume was investigated by including each of the glutenins as a fixed effect factor in the linear mixed model analysis of loaf volume. Fixed effect means were estimated for loaf volume for each of the levels of the significant glutenin factors.

2.3.2. Results

The genotypes provided a large range of quality test results for all the traits measured. The mean, standard deviation (SD), minimum and maximum for each test are displayed in Table 7 for 2001 Roma harvest, in Table 8 for 2002 Roma harvest and in Table 9 for 2002 Biloela harvest.

Table 7. Quality test result summary for 30 genotypes grown at Roma during 2001.

Trait	Mean	SD	Min	Max
Loaf volume (cm^3)	807	51	683	920
NIR grain protein (%)	12	0.7	9.7	13.6
Falling number (s)	402	31	326	449
1000 kernel weight (g)	31	2.1	26.6	37.5
Particle size index	13	2	9	16
Milling yield (%)	77	1	75	79
Flour swelling volume (mL)	16	2	14	20
Max. Extensograph extensibility (cm)	22	2	16	27
Max. Extensograph extens/protein (cm)	2	0	1	2
Max. Extensograph resistance (BU)	501	72	246	680
Mixograph stability (min)	6	1	4	9
Farinograph water absorption (%)	63	2	57	70
Farinograph dough development (min)	7	1	4	11

Table 8. Quality test result summary for 30 genotypes grown at Roma during 2002.

Trait	Mean	SD	Min	Max
Loaf volume (cm^3)	833	59	635	950
NIR grain protein (%)	17	1	15	19
Falling number (s)	503	68	377	643
1000 kernel weight (g)	22.5	2.0	19	27
Particle size index	20	1	17	23
Milling yield (%)	73	1	70	76
Flour swelling volume (mL)	15	1	12	17
Max. Extensograph extensibility (cm)	23	3	18	27
Max. Extensograph extens/protein (cm)	1	0	1	2
Max. Extensograph resistance (BU)	662	84	473	865
Mixograph stability (min)	5	1	3	8
Farinograph water absorption (%)	68	2	64	80
Farinograph dough development (min)	9	1	7	12

Table 9. Quality test result summary for 30 genotypes grown at Biloela during 2002.

Trait	Mean	SD	Min	Max
Loaf volume (cm^3)	810	47	703	938
NIR grain protein (%)	13.4	1.0	11	16
Falling number (s)	448	43	347	558
1000 kernel weight (g)	23	2	20	28.7
Particle size index	14	1	11	17
Milling yield (%)	73	1	70	82
Flour swelling volume (mL)	15	1	13	19
Max. Extensograph extensibility (cm)	20	2	16	27
Max. Extensograph extens/protein (cm)	1	0	1	2
Max. Extensograph resistance (BU)	630	62	457	764
Mixograph stability (min)	7	2	4	14
Farinograph water absorption (%)	64	2	58	74
Farinograph dough development (min)	8	1	6	13

The samples from Roma and Biloela in 2002 differed particularly in protein content. All the samples from Roma had a protein content greater than 15% with the exception of one which was slightly less at 14.8% while the samples from Biloela were all less than 15% with the exception of one at 16.1%. The samples from Roma also had relatively lower 1000 kernel weights (20.4 to 28.7g), which suggested that the plants might have been stressed at this site compared to the previous year (Table 7) and also compared to the Biloela 2002 site (Table 9). However it was decided to include the samples from the 2002 Roma site in the study in order to obtain a measure of genotype x environment interaction, as samples were only available from these two sites.

To broadly summarise test-baking results, the average loaf volume achieved by each of the 30 genotypes for both years and sites is displayed in Fig 3.

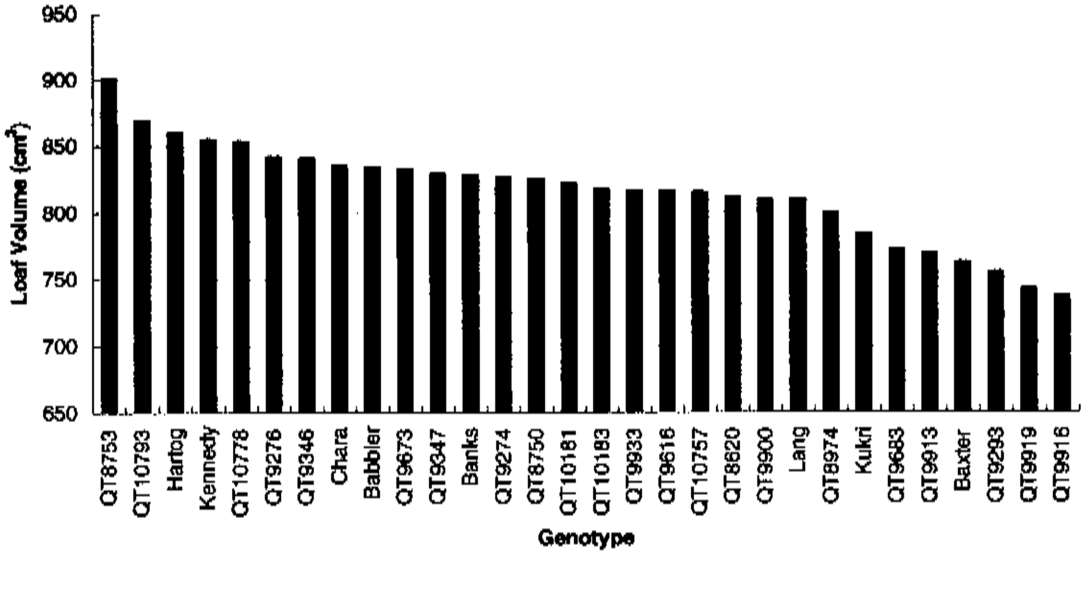

Fig 3. Average sponge and dough loaf volumes for 30 genotypes produced at Roma during 2001 and at Roma and Biloela during 2002.

Estimates of genetic correlations between sites and harvest years were performed to assess the validity of examining combined data in this way. This is discussed in section 3.2.1 below.

3.2.1: Genetic correlations - 2002 harvest

Genetic correlations between the Biloela and Roma sites, 2002 harvest, were determined and are displayed in Table 10. Correlations between sites were greater than 0.6 for all traits except dough development time, NIR protein and 1000 kernel weight. The remaining data was combined for all further analysis.

Table 10. Genetic correlations between 2002 harvest sites.

Trait	Genetic correlation between sites, Biloela and Roma 2002
Loaf volume (cm^3)	0.921
NIR grain protein (%)	0.559
Falling number (s)	0.706
1000 kernel weight (g)	0.164
Particle size index	0.754
Milling yield (%)	0.658
Flour swelling volume (mL)	0.947
Max. Extensograph extensibility (cm)	0.639
Max. Extensograph extens/protein (cm)	0.714
Max. Extensograph resistance (BU)	0.885
Mixograph stability (min)	0.703
Farinograph water absorption (%)	0.969
Farinograph DDT (min)	0.399

3.2.2: Genetic correlations - 2001 and 2002

The analyses showed that a common correlation between the three sites for sponge and dough loaf volume was not suitable and separate predictions were required for 2001 and 2002, (Table 11). The analyses also showed that dough development time, 1000 kernel weight and falling number had low common correlation between the three sites and so also required separate predictions. In addition, extensibility/protein demonstrated convergence problems excluding it from further analysis. For all other traits, an overall genotype effect was predicted, on the basis of a moderate to high (>0.6) genetic correlation common to all pairs of sites.

Table 11. Genetic correlations of traits, between 2001 and 2002 indicate that data for loaf volume, dough development time and falling number cannot be pooled for analysis.

Trait	Common correlations between sites	Biloela 02 + Roma 01	Biloela 02 + Roma 02	Roma 01 + Roma 02
Loaf volume (cm^3)	-	0.559	0.904	0.505
NIR grain protein (%)	0.857			
Falling number (sec)	0.070*			
1000 kernel weight (g)	0.565*			
Particle size index	0.637			
Milling yield (%)	0.628			
Flour swelling volume (mL)	**			
Max. Extensograph extensibility (cm)	0.768			
Max. Extensograph resistance (BU)	0.832			
Mixograph stability (min)	0.808			
Farinograph water absorption (%)	0.959			
Farinograph DDT (min)	0.505*			

*predictions for each of the 3 sites while all other traits have one average prediction over the 3 sites

** genotype x environment interaction component very small

3.2.3: Principal component analysis

Best linear unbiased predictors (BLUPS) from the individual trait analyses (Appendix 2) were used as input to a principal component analysis. This principal component analysis resulted in the bi-plot displayed in Fig 4. The biplot shows the relationship between the quality traits and sponge and dough loaf volumes. It also superimposes the genotype scores on each of the axes. Low genetic correlations between sites and seasons (Table 11) meant some data could not be pooled and so are displayed separately on the bi-plot.

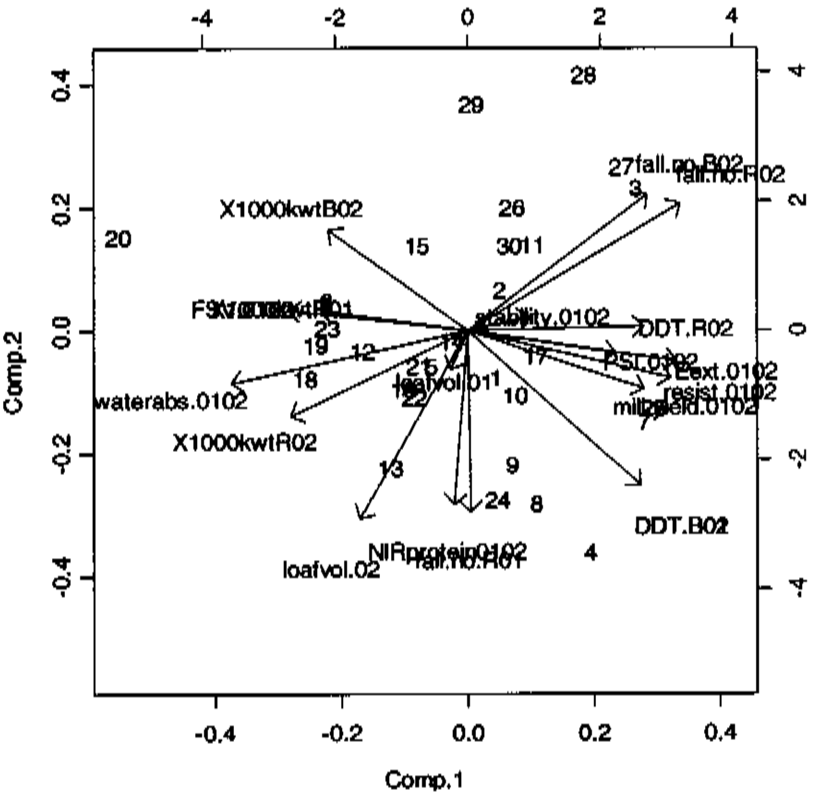

Fig 4. A biplot of 30 genotypes (labelled 1-30*), from Roma in 2001 and Roma and Biloela in 2002, for the given quality traits.
*Babbler 1, Banks 2, Baxter 3, Chara 4, Hartog 5, Kennedy 6, Kukri 7, Lang 8, QT10181 9, QT10183 10, QT10757 11, QT10778 12, QT10793 13, QT8620 14, QT8750 15, QT8753 16, QT8974 17, QT9274 18, QT9276 19, QT9293 20, QT9346 21, QT9347 22, QT9616 23, QT9673 24, QT9683 25, QT9900 26, QT9913 27, QT9916 28, QT9919 29, QT9933 30.

3.2.4: Relationships between quality traits and loaf volume

Genetic correlations are adjusted for sources of variation in the work such as site, genotype, field trial, milling process and laboratory variation. Genetic correlations of all the test results with sponge and dough loaf volume are displayed in Table 12. A low variance component for genotype by environment interaction prevented determination of correlations for falling number and particle size index.

Table 12. Genetic correlations of quality traits with loaf volume for 2001 and 2002 harvests, Roma and Biloela.

	Genetic correlation with loaf volume		
Trait	Roma 2001	Roma 2002	Biloela 2002
NIR grain protein (%)	-	-0.176	0
Falling number (s)	-	-	-
1000 kernel weight (g)	-	0.618	-0.292
Particle size index	-	-	-
Milling yield (%)	-0.307	-0.200	0.480
Flour swelling volume (mL)	0.493	0.595	0.637
Extensograph extensibility (cm)	-0.026	-0.229	0.188
Extensograph resistance (BU)	0.381	-0.357	-0.075
Mixograph stability (min)	0.517	-0.297	-0.140
Farinograph water absorption (%)	-0.095	0.332	0.280
Farinograph DDT (min)	-0.208	-0.149	-0.141

3.2.5: Glutenin subunits and granule bound starch synthase (GBSS).
Determination of the glutenin alleles present and status of the Wx-B1 loci important for encoding the GBSS proteins was completed for all the genotypes in the trial, and full results are contained in Appendix 4. A limitation of the glutenin data is that there are 18 different glutenin patterns present among the 30 genotypes in the trial, indicating an insufficient number of individuals to fully explore the glutenin effects.

Individual glutenin effects were tested, however, and are displayed in Table 13. They must be interpreted with caution.

Table 13. The effect of Glutenins and Wx-B1 on loaf volume for 2001 and 2002.

Trait	P value for 2001	P value for 2002
Glu-A1	NS	NS
Glu-B1	0.01**	NS
Glu-D1	NS	NS
Glu-A3	NS	NS
Glu-B3	NS	0.018*
Glu-D3	0.055	0.025*
Wx-B1 status	0.09	0.034*

2.4. Discussion

The genotypes selected for this work exhibited a large range of quality characteristics and sponge and dough loaf volumes. The exception was particle size index, but this small range was expected since only hard wheats are used for bread making and no soft wheats were present in this trial.

In general, genotype by environment interaction was low for most quality traits. Both sites in 2002 provided supporting information on the quality of the genotypes except for the traits, grain protein, 1000 kernel weight and farinograph dough development time. Similarly, most traits, except loaf volume, dough development time, 1000 kernel wt and falling number, were pooled for analysis across 2001 and 2002.

While there was little genotype by environment interaction for most of the measured traits, the inter-trait relationships, particularly those with loaf volume, did vary across environments. Some of this variation could be due to the very high grain proteins achieved by samples produced at Roma during 2002. However if protein alone were responsible for differences in genetic correlations of tests with loaf volume from season to season, we would expect correlations for Roma 2001 and Biloela 2002 to be similar, and they are not. Speculating on environment interactions with grain quality is probably beyond the scope of this work.

However to be useful in wheat breeding, associations of tests with loaf volume need to be robust enough to be expressed from season to season.

Flour swelling volume was the only trait exhibiting a significant correlation with sponge and dough loaf volume. This positive correlation is evident across sites in both years, indicating some stability of the effect across environments. In this study the relationship was observed across a range of grain proteins, indicating that this test could be a useful indicator of sponge and dough loaf volume.

Analysis of relationships between glutenin sub-units needs to be interpreted with caution, because some glutenin patterns are represented by only one or two genotypes. Further work with a greater number of genotypes representing selected glutenin patterns is required to understand the importance of glutenin subunits for sponge and dough bread quality.

Overall, the results indicated that no single quality trait could encompass what is important to achieve high loaf volume in sponge and dough bread. Traditional tests of physical dough properties are designed to capture the process of flour mixing and hydration. In addition, traditional quality tests of grain tend to measure flour components separately. Both approaches are complicated by seasonal influence and component interactions. Yet, the traditional tests used in this work have previously allowed development of the many quality wheat varieties present today.

Considering what is different about the sponge and dough system helps determine the best measure for choosing wheats for this process. It is recognised that gluten and starch play an important role in forming the strong gaseous matrix essential for good bread (Gan *et al* 1990). Perhaps their role becomes even more important in the sponge and dough process where fermentation increases the volume of gas, lowers pH and increases dough elasticity. These results also suggest that considering glutenin and Wx-B1 associated starch effects may also provide a better guide for breeders developing wheats for this expanding market. Based on the information reported here and given the limitations with the understanding from this work of the relationship between glutenin subunits and sponge and dough bread quality, it is proposed that breeders should use the quality test of flour swelling volume in order to predict sponge and dough loaf volume. However, in recognising the usefulness of the flour swelling volume test, it is considered that test baking of selected advanced lines would still be necessary.

While this study has demonstrated a strong relationship between sponge and dough loaf volume and flour swelling volume there exists the challenge of combining good qualities for sponge and dough bread and yellow alkaline noodles in the one variety. Encouraging results to demonstrate that such a goal is achievable were illustrated when the best performing genotype for sponge and dough loaf volume in this study, QT8753 also has shown excellent results for the development and stability of yellow alkaline noodle colour. However the challenge of successfully achieving such a combination in the one variety could be complicated from a noodle textural perspective, as earlier work showed that flour swelling volume of flours was negatively correlated with alkaline noodle firmness and elasticity, and positively correlated with surface smoothness of cooked noodles (Ross *et al* 1997).

Even though measures of dough strength such as extensograph resistance have been suggested as important for sponge and dough loaf volume, the results of this study did not support such a link. Interestingly the dough strength of the better performing genotype, QT8753 was only slightly higher than the results obtained for Alsen (mean of 626 BU for all samples of QT8753 evaluated in 2002 compared to 565 BU for Alsen) and in turn similar to reported results of 670 and 665 BU for 13.5 and 14.5% protein content samples respectively for No. 1 Canada Western Red Spring wheat from 2002 harvest (Preston *et al* 2002).

Alternatively, new techniques could be investigated and developed to replace the traditional tests of wheat quality employed here. Novell tests employed recently in the US and Canada has shown very strong correlations with sponge and dough loaf volume. In the US, Wang and Sun (2002) demonstrated that creep recovery of flour–water doughs had a correlation of 0.939 with bread volume. The authors proposed that the elasticity measured by recovery strain assessment was an important factor for this result. If the predictive power continues beyond the eleven commercial flour samples used, the test could prove practical for end product selection in wheat breeding, as it only requires 0.5g of dough at constant water absorption.

Similarly, in Canada, a derivative of the sedimentation test, (Zeleny *et al* 1960), the sodium dodecyl sulfate (SDS) protein gel test, has recently been modified to reduce sample size to less than 1 g and used to predict bread loaf volume achieving R^2's of 0.89 and 0.95 for flour and ground wheat respectively (Sapirstein and Suchy 1999). Again the test could have excellent potential in wheat quality screening if reproducibility extends beyond the seven Canadian commercial wheat flours used in the study.

Early selection in breeding programs may also be achieved with near infrared techniques. Calibrations to detect the key constituents for baking performance could be developed based on flour or ground grain from wheats with a range of sponge and dough quality. The technology is fast and only requires small amounts of grain but success is dependant on attaining suitable samples for the calibration. Recent work has demonstrated that by using native substrates such as gliadin and glutenin in wheat (Wesley *et al* 1999; 2001) and hordein in barley (Fox *et al* 2002), important information on spectra associations with protein fractions can be attained.

While the need for more derisive wheat quality tests is indisputable, this work has confirmed that Australia can produce wheats suitable for sponge and dough bread. A sample of Alsen, a North Dakota Hard Red Spring wheat grown in Queensland from imported seed, was milled, quality tested and baked with the project samples. When produced in the US, Alsen has demonstrated excellent sponge and dough bread quality. Limited analytical data is listed in Appendix 3 for comparative purposes. The sample of Alsen produced in Queensland, performed better than many genotypes in the project but provided a smaller loaf volume than our best performing genotype, QT8753 (Fig 5). Certainly the quality attributes of Alsen could be very different when grown in the US. In Fig 5, it is also notable that Alsen provided a loaf volume very similar to that of Premium Asian milled flour; a logical result since Alsen is produced in the US for this market.

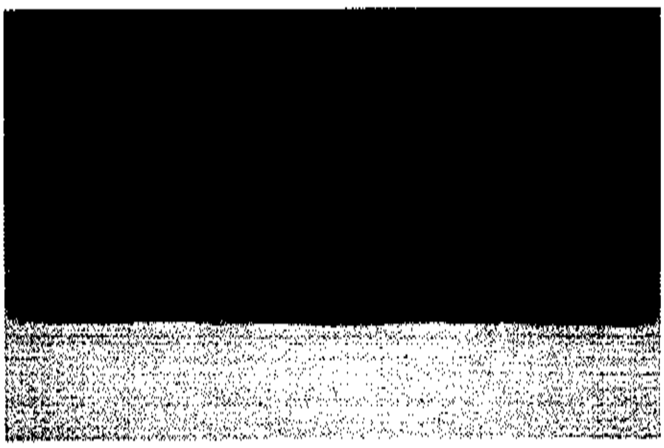

Fig 5. Loaf volumes for the genotype QT8753, Premium Asian milled flour (AMF) and the US spring wheat variety, Alsen, grown in Queensland, was 910 cm^3, 845 cm^3 and 830 cm^3 respectively.

2.5. Conclusion

- Tests for dough strength did not relate significantly to sponge and dough loaf volume despite suggestions that dough strength is a critical factor for this product.

- The quality test with the most significant and strongest correlation with sponge and dough loaf volume was flour swelling volume. This test, which was positively correlated with loaf volume, was significant for the samples from the site in 2001 and for those from both sites in 2002 despite the presence of differing protein contents. Consequently the robustness of this test indicates that it may be a useful indicator of loaf volume. It would not, however, have predictive potential as only a small percentage of the variation in sponge and dough loaf volume was explained.

- Selected glutenin alleles and the null form of the Wx-B1 allele may be associated with sponge and dough loaf volume however since some glutenin patterns were only represented by one or two genotypes, the limited results of this study need to be interpreted with caution. It is important to stress that additional work with a number of genotypes representing selected glutenin patterns is required in order to understand the importance of glutenin subunits for sponge and dough bread quality.

- In this study, the best performing genotypes identified for sponge and dough loaf volume were the Batavia/Pelsart crossbreeds QT8753, QT10793 and QT10778. Hartog and Kennedy also performed well. Some of these entries, in particular QT8753 have shown in other work excellent noodle sheet colour when made into yellow alkaline noodles. These results indicate that it would be possible for Australia to produce wheats with good sponge and dough bread quality combined with very good noodle sheet colour when producing yellow alkaline noodles.

- This study has confirmed that Australia can produce wheats suitable for sponge and dough bread. Limited comparative work showed that the loaf volume obtained with the better performing genotype, QT8753 was better than the US variety, Alsen and the Premium grade Asian milled flour.

2.6. Acknowledgement

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2.8. Appendices, Section 2

Appendix 1. Analytical data* for Premium, Standard and All-Purpose grades of Asian milled flour

	Premium bread flour	Standard bread flour	All purpose flour
Protein (%)	13.8	13.1	11.7
Ash (%)	0.53	0.54	0.51
Farinograph			
Water absorption (%)	65.4	64.2	61.2
Development time (min)	10.2	6.7	4.5
Departure time (min)	18.0	13.2	11.0
Extensograph			
Max. Extensibility (cm)	20.7	17.5	17.5
Max. Resistance (B.U.)	480	505	495
Area (cm^2)	137	126	124

*Data was supplied by manufacturer from the analysis of a larger flour sample from which these sub samples were obtained.

Appendix 2. Best linear unbiased predictors for the various grain, flour, physical dough and baking quality tests for the 30 genotypes from Roma in 2001 and Roma and Biloela in 2002

Genotype	NIR protein 0102	mill yield 0102	fall no B02	fall no R01	fall no R02	1000kwt B02	1000kwt R01	1000kwt R02	PSI 0102	loafvol 02	loafvol 01	FSV 0102	waterabs 0102	DDT B02	DDT R01	DDT R02	Eext 0102	resist 0102	stability 0102
Babbler	14.3	74.0	446	411	500	22.3	29.9	22.0	16	827	833	13.3	66.0	8.3	6.6	10.0	24.0	525	5.4
Banks	14.3	75.2	451	400	545	22.2	29.7	21.3	15	818	829	13.8	65.1	7.5	6.1	7.7	23.8	532	5.0
Baxter	14.1	74.8	465	384	602	25.5	33.0	22.1	16	758	830	14.6	63.3	9.2	7.2	11.2	24.9	644	6.3
Chara	14.9	74.9	443	369	488	22.1	31.7	23.8	16	855	799	14.4	64.1	10.4	8.0	10.0	26.0	655	4.9
Hartog	13.8	74.6	439	404	452	23.5	31.2	21.8	14	847	850	16.3	64.4	8.6	6.9	9.8	21.7	618	7.3
Kennedy	14.2	74.3	435	377	410	25.5	32.4	23.5	15	848	822	17.0	64.1	6.9	5.7	8.7	22.6	643	6.8
Kukri	14.6	74.8	452	403	540	24.2	31.7	21.5	15	782	786	14.7	62.4	11.4	8.6	10.3	22.6	641	6.5
Lang	14.6	74.7	445	421	461	22.2	29.3	22.3	17	821	787	14.3	65.6	9.5	7.4	8.3	23.7	611	5.2
QT10161	14.6	74.4	444	425	502	23.7	31.3	22.7	16	816	822	13.9	65.2	9.4	7.4	8.4	24.4	591	5.1
QT10183	14.2	74.8	445	416	475	23.2	30.8	22.2	16	805	826	14.1	64.4	8.8	7.0	8.7	24.1	589	5.5
QT10757	14.6	74.3	459	401	555	23.0	30.1	21.2	15	779	814	14.4	64.7	7.8	6.4	9.4	22.3	604	5.4
QT10778	14.1	73.8	438	397	456	23.9	31.0	22.3	15	856	847	17.2	65.6	7.9	6.4	8.9	23.0	571	5.0
QT10793	14.6	73.1	440	415	451	23.0	29.2	21.7	15	871	853	16.3	67.3	8.6	6.8	8.5	22.8	606	4.8
QT8620	14.2	74.6	445	403	514	22.8	30.6	23.1	15	833	751	14.3	65.3	8.2	6.6	8.3	22.2	560	6.4
QT8750	14.4	74.3	453	383	496	23.8	31.2	22.0	16	821	806	16.8	65.2	7.3	6.0	8.0	22.8	587	5.0
QT8753	14.4	74.5	446	403	485	24.1	30.5	22.4	15	893	876	17.9	65.2	7.8	6.3	8.7	23.4	586	5.8
QT8974	14.3	75.2	446	407	475	22.2	29.8	21.3	17	799	798	14.7	64.3	8.1	6.5	8.6	22.6	608	5.2
QT9274	14.2	74.3	443	434	432	24.3	33.0	23.7	15	820	833	16.3	69.0	7.6	6.2	8.2	22.5	550	5.9
QT9276	14.6	74.5	451	421	502	24.9	33.8	23.6	15	867	795	16.4	70.1	7.1	5.9	9.5	23.0	493	5.2
QT9293	14.7	73.1	440	356	428	27.4	35.7	25.4	15	774	750	17.5	71.8	7.8	6.4	7.3	19.5	446	4.5
QT9346	14.2	74.3	449	427	519	22.7	30.5	22.7	15	861	786	14.2	66.3	7.9	6.4	8.0	22.3	506	5.3
QT9347	14.6	74.0	446	424	476	23.6	31.8	22.7	16	827	819	13.9	66.0	8.1	6.5	7.7	22.2	549	5.4
QT9616	14.0	74.1	444	413	464	23.6	32.9	25.0	15	824	795	14.3	65.6	7.6	6.2	7.5	21.1	523	5.0
QT9673	14.4	74.8	447	429	487	23.2	31.6	24.1	15	846	803	14.3	65.2	9.4	7.4	9.5	23.6	621	4.2
QT9683	14.6	75.6	460	429	562	23.4	31.4	22.3	17	804	758	14.4	63.9	9.4	7.3	10.0	24.8	663	5.0
QT9900	13.6	74.4	451	378	519	22.2	30.7	22.2	15	817	794	14.2	63.9	7.7	6.3	10.5	22.2	598	6.1
QT9913	13.8	73.7	458	387	585	23.3	30.0	21.4	17	756	822	15.0	62.3	8.4	6.7	10.2	24.2	656	5.7
QT9916	14.0	74.5	463	357	586	24.5	31.1	21.6	16	736	770	14.6	62.7	8.0	6.4	9.3	25.3	561	4.9
QT9919	13.8	74.0	450	370	518	23.7	29.6	21.0	16	733	808	14.7	64.4	7.1	5.9	7.0	23.5	573	5.2
QT9933	13.6	74.7	444	385	512	24.2	31.6	21.1	15	817	810	14.3	64.1	8.3	6.6	9.8	22.8	599	6.1

Appendix 3. Analytical data for the US spring wheat variety, Alsen when grown at Wellcamp, Queensland in 2002

Trait	Alsen
Flour swelling volume (mL)	16
Farinograph	
Water absorption (%)	66.8
Development time (min)	9.0
Extensograph	
Max. Extensibility (cm)	23.9
Max. Resistance (B.U.)	565

Appendix 4. Glutenin subunits, null 4A status and predicted (BLUP) loaf volumes of genotypes. Standard errors for predicted loaf volumes for 2001 were from 18 to 20 and for 2002 were from 11 to 12.

Genotype	Loaf volume 2001	Loaf volume 2002	Rank 2001 2002	Glu-A1	Glu-B1	Glu-D1	Glu-A3	Glu-B3	Glu-D3	Wx-B1
QT8753	876	893	1	a	u	a	b	b	c	b
QT10793	853	871	2	a	u	a	c	b	c	b
QT10778	847	856	3	a	u	a	c	b	c	b
QT8750	806	820	11	a	u	a	c	b	c	b
QT10757	814	779	15	a	u	a	c	b	c	a
Hartog	850	847	4	a	i	d	b	h	b	b
Kennedy	822	848	5	a	i	d	b	h	b	b
Babbler	833	827	5	a	iu	a	b	b	c	a
QT9274	833	820	6	a	i	ad	c	h	b	b
QT9347	819	827	7	a	u	a	e	b	c	a
Chara	799	855	8	b	al	a	b	b	b	ab
QT9276	795	866	8	a	i	a	c	h	b	b
Banks	829	818	8	b	u	a	b	b	c	a
QT10181	822	817	11	b	u	a	b	b	c	a
QT9346	786	861	10	a	f	a	c	b	c	a
QT10183	826	805	10	a	u	a	b	b	b	a
QT8620	751	833	15	a	u	a	b	b	b	a
QT9933	810	817	12	a	u	a	b	b	b	a
QT9900	794	817	16	a	u	a	b	b	b	a
QT9673	803	846	9	a	u	a	c	b	b	a
QT9616	795	824	13	a	u	a	c	b	b	a
QT8974	798	799	17	a	u	a	c	b	b	a
Lang	787	821	14	a	u	a	bc	b	b	a
Baxter	830	758	13	a	f	a	b	h	a	a
QT9683	758	804	20	a	f	a	b	h	a	a
QT9919	808	733	18	a	i	a	b	h	b	a
Kukri	786	783	19	a	al	d	d	h	b	b
QT9913	822	756	15	b	f	a	b	d	a	a
QT9916	770	737	21	b	f	a	b	d	a	a
QT9293	750	774	21	a	C	a	b	j	c	b

Section 3

Method Development

The first stage of this project was the development of a test baking method that could be shown to produce similar sample rankings and levels of discrimination to those measured by Asian flour millers and bakers.

After meetings were held with Singapore companies: Prima Flour Mills, Gardenia Bakeries and Sunshine Bakery, and Malaysian companies Bonjour Bakery and Federal Flour Mills, a sponge and dough test method was developed on a one kilogram scale. A description of the method is attached in Appendix 1 (Attached at the end of the report).

The method appeared to provide effective discrimination between samples and was demonstrated to have good reproducibility. Samples were then exchanged between Prima Flour Mills, BRI Australia and Bonjour Bakery. These included commercial flours and a sample of flour milled from the wheat variety Kennedy. The ranking and level of discrimination between the laboratories was very similar. The BRI method was then introduced for the evaluation of new wheat crossbreds in the National Wheat Quality Evaluation Program.

Table 1. Flours compared for test baking by Prima, Bon Jour and BRI

	Prima "C"	Prima "G"	Bon Jour	Federal 1	PH	Kennedy
Flour						
Protein (%, N x 5.7) 14% moisture basis	13.0	13.0	13.5	14.0	12.5	12.7
Starch damage (%)	7.9	8.2	8.2	10.0	6.8	6.6
Ash (%) 14% moisture basis	0.49	0.52	0.55	0.53	0.54	0.48
Farinograph - water absorption (%)	62.7	63.8	65.5	69.0	62.4	67.8
- development time (min)	10.1	9.1	9.5	18.6	7.5	10.6
Extensograph - extensibility (cm)	13.4	17.8	21.5	20.5	21	16.9
- maximum height (BU)	995	900	635	635	550	900
Amylograph (250cmg head) Peak Height	615	805	800	595	NA	NA
Test bake score Asian Lab 1	91	90.75	NA	NA	NA	91.25
Test bake score Asian Lab 2	NA	NA	88	90	NA	91
Test bake score BRI	69	67	64	65	56	71

The BRI method was then used as a basis for the development of a smaller scale method at QDPI. A smaller scale method was required as the sample size available from the field trials was restricted. Samples and personnel were exchanged between BRI and QDPI in the development of an effective test based on a total of 200g of flour. Once the QDPI method was completed it was applied to the evaluation of the field trial material.

At BRI further work was undertaken to reduce the scale of the one kilogram method. This work was undertaken as the Hobart mixer used for the method provided little opportunity to control dough temperature and the scale of the method restricted the NWQTP to a single test bake. A new method using a 300g farinograph bowl driven by a Brabender dough corder was developed. Comparisons between the original sponge and dough and test scale methods were completed. The small scale method resulted in similar ranking and discrimination between samples. The small scale methods allows up to three test bakes to optimise the mixing time and water addition whilst still using less than one kilogram of flour.

Section 4

Bread Processing

2.1 Bread Ingredients

A commercial bread improver developed for sponge and dough bread production was evaluated using the new small scale test baking system. The commercial improver provided significant improvement to loaf volume and score for all flour samples evaluated. It was found that the improver increased the bread score of flours milled from new crossbreds targeted at the Australian Prime Hard class to those of the excellent sample of Kennedy which was equivalent to commercial baking flours from Asia. When the improver was added to the Kennedy it also demonstrated significant improvement (Fig 1).

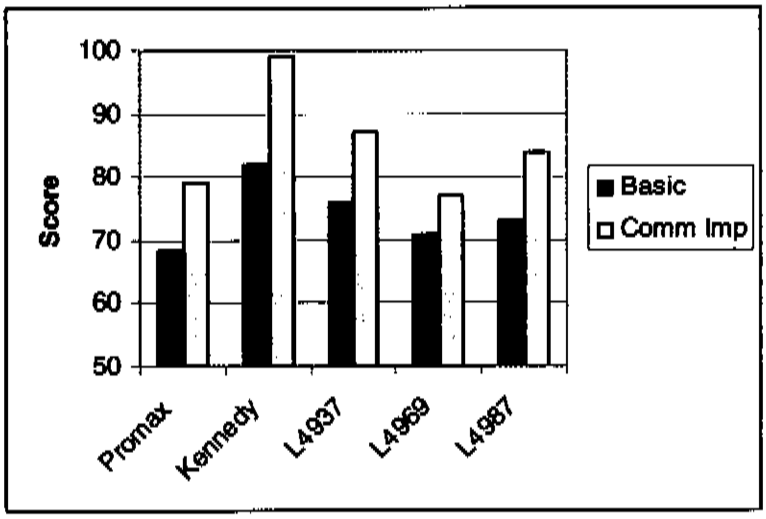

Fig 1. Commercial bread improver evaluated with a series of flours representing a range of baking performance

These results indicate that use of ingredients can only partially substitute for flour quality. Sponge and dough bread markets will need to determine the most economic combination of flour quality and ingredients to achieve the bread products they require. From the millers perspective, delivering flour with better performance has clear advantages, it is then up to the baker to decide what level or cost of ingredients they will add. In the above case the domestic Australian company is able to use local flour and produce an acceptable product with the sponge and dough process. However in Asia where there is greater choice of flour and higher consumer expectations of sponge and dough bread it could be expected that the combination of flour and ingredients will be optimised to provide outcomes more similar to the Kennedy sample baked with the commercial improver.

To determine the effect of bread improver components a response surface methodology design (incomplete block) was used to evaluate four enzymes and SSL.

The enzymes provided by Novozyme and tested were:

Gluzyme
Pentopan
Novamyl
Lippopan

The flour used was a low extraction sample taken from a pilot milling of a commercial bakery grist with a flour protein content of 11.5% and ash of 0.48. This sample was demonstrated to produce good bread quality using the commercial sponge and dough improver.

Results summary

1. SSL did not appear to have significant effects.
2. Gluzyme was not very effective
3. Four combinations tested produced loaf volumes greater than the commercial reference sample, three of these four runs did not have any addition of Gluzyme or SSL
4. The highest loaf volume was achieved with Novamyl and Lippopan each at 18ppm.
5. The highest score achieved with the ingredient combination was eight points higher than when no additional ingredients were added.
6. The highest loaf score was achieved with Gluzyme 5ppm, Pentopan 90ppm, Novamyl 10ppm, Lippopan 10ppm and SSL 0ppm. This score was still five points below the commercial reference.

The increased score from the addition of enzyme combinations was highly significant and using what was pretty standard Australian wheat of moderate protein content it was possible to achieve scores similar to commercial sponge and dough flours, when tested with a base improver. The commercial improver was significantly better again and further work is required to determine the source of this difference.

It may be that effective formulation of improvers can bridge the gap for Australian wheats and make them viable in sponge and dough markets. Further work is required to refine this component of the project.

2.1.1. Ingredient variations

Further ingredient trials were completed to evaluate the impact of each of the ingredients used in the standard baking procedure (Appendix 3.1). The results are presented as the conclusions to this work.

1. Malt flour at 0.5% produced the best loaf score (better than 0.25 and 0.75%)
2. A combination of malt flour and 10 ppm fungal amylase provided the best score (levels of Biozyme from 0 to 30ppm were tested).
3. When used without malt flour the level of 20ppm fungal amylase provided the best result and it was apparent that this could be substituted for the use of malt flour.
4. Calcium orthophosphate at 0.25% produced the best outcome (compared to 0 and 0.5%).
5. Ammonium sulphate at 0.06% produced the best result (range tested from 0 to 0.12%).

6. Fat levels in the formulation were optimised at 3% when compared to 0 and 6%. However this will depend on the market requirements. This result indicates that working at higher fat levels does require formula adjustments.
7. Sugar use in the formulation was optimised at 5% when compared to 0 and 10% (Fig 2). Again this will depend on market preference, however clearly adjustments need to be made to optimise the formula for the level of sugar.

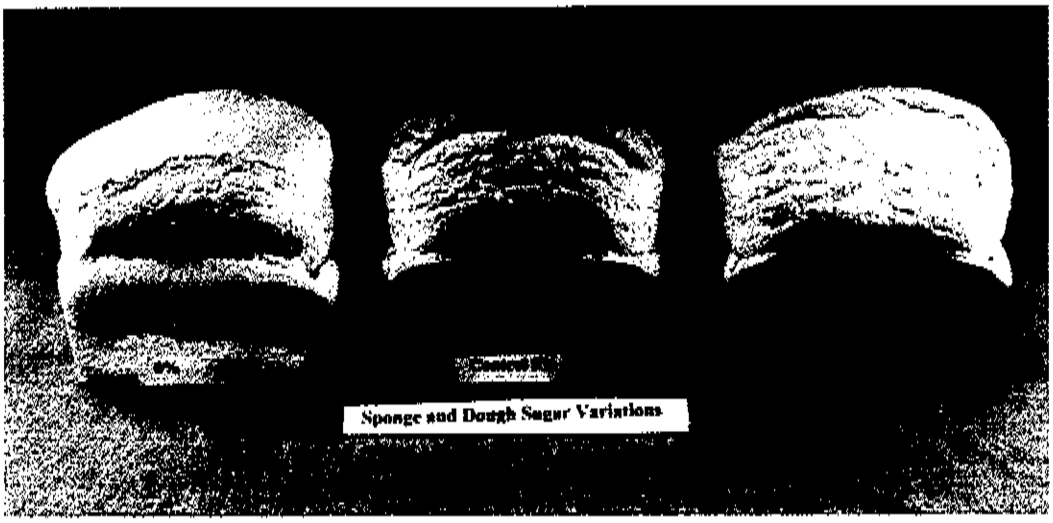

Fig 3. Variation in sugar addition to the sponge and dough formula

8. Loaf volume and loaf score were quite stable at -2% and +2% from the optimum water addition indicating that within this range acceptable estimates of baking quality would be achieved (Fig 4). At higher water addition levels the dough would not have been suitable for processing in an automated plant.

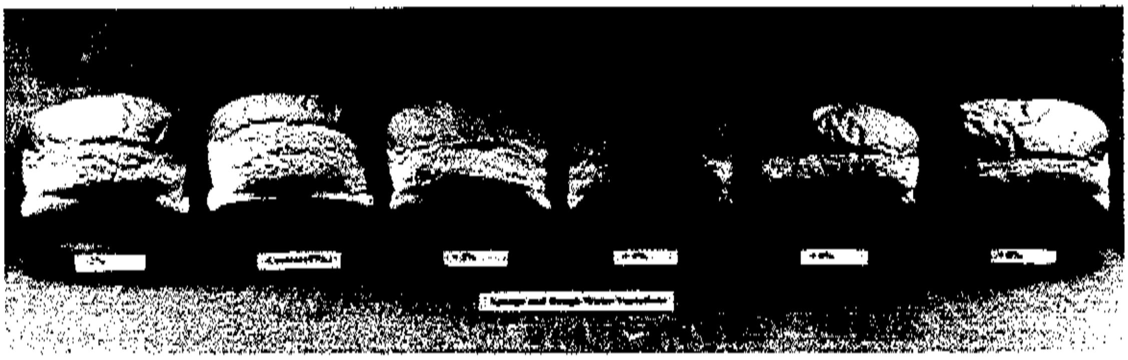

Fig 4. Variation in total water addition, the different quantities were added at the dough stage.

4.2. Processing

The following processing conditions were evaluated for their influence on the final product.

1. The formula selected including yeast levels was optimised to suit a finished sponge temperature of 26°C (range tested from 24 to 28C).

2. The effect of sponge time was to increase the score as the time increased from 2 to 5 hrs. Commercial practice is commonly 3.5 to 4 hrs (Fig 5).

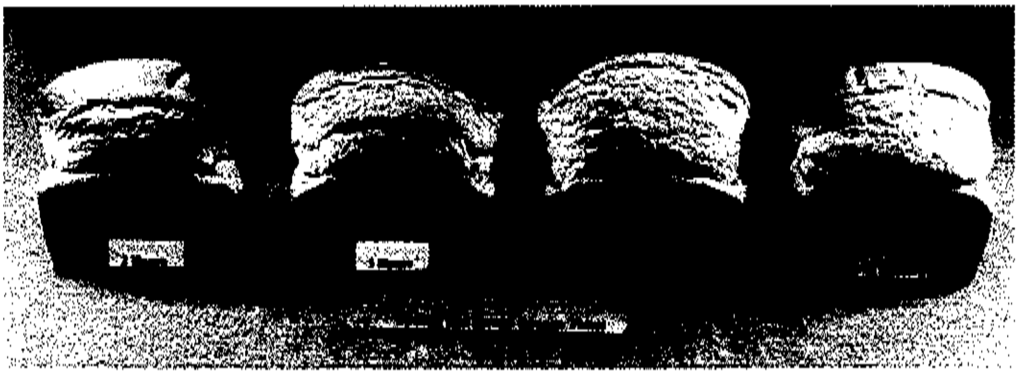

Fig 5. Influence of sponge time.

3. The system was quite sensitive to the correct mixing time for the flour tested. Both under and over mixing resulted in a reduction of the loaf quality (Fig 6). The sponge and dough system was considered more sensitive to mixing time under these circumstances. This is a point that has been raised specifically by Asian millers and bakers where they rate tolerance to mixing in the sponge and dough system very highly and this should be taken into account in evaluations.

Fig 6. Effect of over mixing on the sponge and dough system for the reference flour used. This flour was sensitive to over mixing which is considered undesirable in Asia.

4. Whilst loaf volume increased with additional proof time the score and tolerance to stress was found to decrease.