BRI22

Dough strength and mixing characteristics for hard wheats

PROJECT DETAILS

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PROJECT TITLE:	DOUGH STRENGTH AND MIXING CHARACTERISTICS FOR HARD WHEATS
START DATE:	01.07.1990
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Summary

Pan bread is a major end product produced from wheat. Hard wheat varieties are suitable for this type of bread. The relationship between physical dough test results and bread making performance was examined. Various Australian hard wheat varieties were used in this project as well as other leading wheat grades from Canada and the USA.

Standard instruments such as the farinograph, the mixograph, the extensograph and the alveograph were used to characterise flour samples. Standard procedures were altered in an attempt to improve the relationship between these tests and test baking results.

The most common instrument for characterising mixing properties in Australia is the farinograph. The farinograph development time, as determined by the standard method, did not relate to the optimum mixing time in the bakery (determined by optimum loaf score). However if the speed of the farinograph mixer was increased markedly above that used in the standard procedure, this relationship improved dramatically. One reason for this is that the higher mixer speed provided a work input rate closer to that achieved with a bakery mixer. The mixograph and the test bakery pin mixer also provided mixing curves which related well to the bakery mixing requirement.

This study developed evidence for increased mixing requirements in the absence of potassium bromate in rapid dough systems. In a study using commercial scale equipment undermixing was shown to be a serious threat to bread quality. The work also indicated a high tolerance to high mixing inputs in current Australian wheats. This result strengthened the need to develop predictive mixing tests that are relevant to commercial mixing. The Bread Research Institute has used this work to

support greater awareness of correct mixing in the baking industry to ensure that bakers reduce the problems associated with wheats with a high mixing requirement. In the last five years undermixing has been identified as the major source of bread making faults in Australia. This project combined with BRI's training and technology transfer have significantly reduced the occurrence of this problem.

Mixing input was shown to have a greater effect on loaf quality than did the water level. Longer mixing times were shown to improve loaf volume, score and crumb softness. Higher water levels resulted in a softer crumb.

Neither mixing input nor water level had an effect on staling rate. Data from this study on the advantages of bakery yield and crumb softness through higher water addition has been specifically used by the AWB to promote the advantages of Australian wheat.

The extensograph and the alveograph instruments are used to measure the strength of dough. The alveograph is not generally used in Australia but is used in other countries. The alveograph was compared to the extensograph which is predominantly used in Australia. This included modifications to the alveograph method.

The extensograph test related better to baking performance than did the alveograph test. Dough strength in Australia is often defined by maximum resistance on the extensograph. However, our results showed that the height (maximum resistance) and the length (extensibility) are both equally important for good bread. Indicating that studies aimed at addressing issues of dough strength must include extensibility.

A compression test to measure dough strength was also developed which related to baking performance. Further work is required in developing this test which may potentially provide a better relationship to baking performance than the extensograph.

As a consequence for the push for increased dough strength to improve the marketability in overseas markets, the mixing time to develop doughs has increased in commercial bakeries. One of the aims of this project was to determine if dough strength was directly related to mixing requirement. Results from this project have shown that there is a close relationship between the strength of dough, as measured by the extensograph and alveograph, and mixing requirement.

Wheats were identified with shorter mixing requirements which produced good quality bread in rapid dough systems, however it appears that they may not have the strength for more stressful baking systems such as the sponge and dough system commonly used in Japan, Taiwan and S E Asia. This study was not able to identify truly strong wheats with low mixing requirements. It will therefore be critical to separate wheats based on strength and mixing for appropriate markets. The mixing tests presented in this report provide more effective measures of mixing to assist selection and segregation of wheat for appropriate marketing.

Further work is required to address measures of strength and elasticity. The results emphasised that strong wheats require extensibility (a balance of dough properties) for bread making. Future work on the development of strong and extensible wheats must be supported by effective mixing, strength and extensibility tests.

Old or Archival Reports (Projects that concluded in 2007 or earlier)

Recommendations

1. This study confirms use of the mixograph as an effective test for characterising mixing behaviour, applicable to the rapid dough process. The mixograph is well suited to use in breeding programs. No adjustment to the standard formulation is required for this testing. This is a particularly valuable outcome with the development of the 2g mixograph. Further testing is required to confirm the exceptional relationship between the mixograph time-to-peak and the bakery mixing requirement.

2. We recommend that the standard farinograph test is adjusted such that the mixer runs at 180 rpm as this better characterises mixing behaviour. Excellent reproducibility in the time-to-peak has been achieved at this speed. The standard farinograph development time does not relate to the bakery mixing requirement.

In the standard method the water is added so that the curves peak at a constant consistency. This is known as the farinograph water absorption, which will be affected by the higher speed. Thus, further work is required in determining an alternative arbitrarily chosen constancy for the curves to peak. This should also relate to the baking water requirement. Investigate a method of adapting existing farinographs to run at 180 rpm. (we have contacted the manufacturers with this request).

3. Further investigation of compression tests and alternative methods of dough deformation for strength and elasticity testing. These methods must be related to baking performance.

4. The extensograph method warrants further investigation. The method followed in Australia mixes all flour to a constant mixing time. The method followed in the USA mixes dough to a peak. It is worth investigating which method best relates to the baking performance of Australian wheats and whether mixing doughs at a higher mixer speed provides a better prediction of baking performance.

5. For commercial operators we recommend the use of test scale mixers which closely resemble the work input rate used in their production when predicting mixing and baking performance.

6. Incorporate systems in test bake methods to ensure full dough development and recording of mixing requirement.

Outcomes

Background

The Australian Wheat board has for some time perceived a need for increased dough strength in Australia's hard and prime hard wheat varieties in order to improve their marketability for bread making on overseas markets.

Wheat breeders have responded to this need through the development and release of a number of new wheat varieties, including Hartog, Suneca and Dollarbird.

One largely unforseen consequence of these newer releases has been that the mixing time required to develop doughs in commercial bakeries has increased significantly (by up to 50%) when the flours used are milled from these wheats. This change in processing requirement has created serious difficulties for many domestic bakeries (loss of capacity and/or quality, increased capital investment requirements) and also for overseas bakeries using the Australian 'rapid-dough' process. This problem was exacerbated in Australia by the removal of Potassium bromate as a permitted ingredient for breadmaking.

Two fundamental questions have arisen out of this experience viz

1. Are dough strength (as measured by extensograph resistance) and dough mixing requirement (commercial scale) directly related, or is it possible to increase dough strength while retaining mixing requirement within acceptable limits?
2. Are conventional small-scale tests for the determination of mixing requirement such as the mixograph and farinograph capable of accurately predicting dough mixing requirements in commercial bakeries?

Answers to theses questions are vitally important for wheat breeders, marketing authorities and flour millers.

To answer the first question effective measures of these parameters are required. This project primarily focussed on defining mixing and strength tests which were relevant to bakery processing and bread quality.

Mixers, processing equipment and the bread manufacturing process have changed over the last 50 years. Higher speed mixers are now used and the fermentation time has been reduced. However, small scale physical dough tests, which are used to predict the performance of a flour, have remained unchanged over the years and do not adequately predict mixing characteristics or baking behaviour with today's processes and equipment. There is a need for better tests which will characterise mixing behaviour and predict baking performance. This project examined the suitability of existing physical dough tests to predict the baking performance of Australian wheat. Modifications to existing tests were attempted and alternative tests were sought.

Project Aims

1. To provide wheat breeders, marketing organisations, flour millers and other purchasers of wheat with an improved understanding of the relationships between the mixing characteristics, dough strength and baking performance of Australia's major hard wheat varieties and of selected grades of overseas wheat.
2. To develop methods for better relating dough mixing parameters - as measured using the mixograph and farinograph - to mixing requirements determined on a commercial scale.
3. To facilitate thereby the improved matching of wheat quality to various market segments and the refinement of quality guidelines for wheat breeders.

Intellectual property summary

There are no developments considered confidential resulting from this study.

Additional information

Communication

Presentation of results at RACI Cereal Chemistry Conferences, Bakery Forums and in publications. Communication of aspects of research through the Bread Research Institute training courses. Training courses provide communication with key industry staff which provides an industry perspective of flour requirements in the domestic market.

Personnel

Project Supervisor:	Dr Ken Quail	(July 1992 - June 1995)
	Mr Micheal McGuirk	(July 1990 - June 1992)
Research Staff:	Mr Steven Zounis	(September 1992 - June 1995)
	Mr John Burrows	(July 1990 - August 1992)

Discussion

1. Research methodology

This project was divided into two components: a) investigating the relationships between small scale physical dough tests and the bakery mixing requirement and b) investigating the relationship between dough strength, as measured by physical dough tests, and baking performance.

The most common tests for characterising mixing behaviour (farinograph and mixograph) and measuring dough strength (extensograph and alveograph) were completed on all our samples and the relationship to test baking results established. Various modifications to the test procedures were made to improve the relationship of these tests and baking results.

Evaluation of baking performance was carried out at the test bakery scale (mixer capacity: 100-200g flour) for a large proportion of this work. However, test baking has been shown to relate to the commercial scale and some experimental work was carried out at a commercial scale in the Bread Research Institute's pilot bakery (mixer capacity: 20-30kg flour).

Samples

To develop tests which will predict baking performance, flour samples with a large range of properties were used. Both pure varieties and blends or mixed grist's were used in various aspects of this work.

A large component of this project investigated the relationship between small scale physical dough tests and baking performance. Australian hard wheat samples and some competitor wheat grades were used. Samples covered a range of protein contents (8.3% to 14.8%) and dough strengths (extensograph maximum resistance, $R_{max,}$ from 250 to 740 BU) (Table I).

TABLE I Flour sample analytical data including: sample number, variety, flour protein content, farinograph water absorptions, extensograph $R_{max,}$ loaf volume and total scores.

SAMPLE NUMBER	VARIETY, GRADE OR SOURCE	PROTEIN CONTENT (%) Nx5.7 13.5% mb	FWA	EXTENSO- GRAPH R_{max}	LOAF VOLUME (MEAN) (cc)	TOTAL SCORE (MEAN) (/100)
01	MIXED (*Australia*)	11.0	63.5	600	777	76
02	CWRS[a] (*Canada*)	14.6	63.2	590	808	80
03	CWRS[a] (*Canada*)	14.8	63.8	450	794	75
04	CPS[b] (*Canada*)	9.9	62.5	540	760	74
05	(*Saudi Arabia*)	12.6	62.6	640	745	72
06	SUNBRI	12.0	63.3	580	803	80
07	SUNKOTA	11.3	64.3	570	726	73
08	SUNECA	13.0	58.7	740	848	80
09	SUNCO	11.5	69.9	500	696	68
10	HALBERD	9.7	62.5	250	664	63
11	HARTOG	12.5	62.0	650	811	78
12	SUNCO	11.5	61.6	500	772	77
13	SUNCO	11.3	65.5	520	781	77
15	SCIPION (*France*)	9.1	57.2	450	706	70

16	SOISSON (*France*)	11.0	53.6	630	758	76
17	CWRS[a] (*Canada*)	13.2	62.0	420	830	77
18	DNS[c] (*USA*)	12.8	64.0	410	810	77
19	QT4546[d] (*Queensland*)	11.1	59.9	500	783	77
20	HARTOG	12.2	67.4	440	824	70
21	BATAVIA	12.8	62.4	440	804	75
22	GAMENYA	8.7	55.2	340	671	61
23	ERADU	9.7	52.0	430	714	66
24	BANKS	10.9	62.6	290	725	71
25	BANKS	12.6	61.2	370	743	76
26	JANZ	11.4	62.1	430	731	73
27	ASW[e] (*New South Wales*)	8.9	57.4	470	740	76
28	ASW[e] (*Western Australia*)	8.3	57.7	350	699	65
29	ASW[e] (*Victoria*)	7.9	55.2	300	648	60

[a] Canadian Western Red Spring
[b] Canadian Prairie Spring
[c] Dark Northern Spring
[d] Australian prime hard
[e] Australian Standard White

Mixing tests

Mixing curves enable the development of dough in a mixer to be monitored and subsequently analysed. The time to peak resistance (TTP) is often considered one of the most important parameters for baking.

Mixing curves were recorded according to the standard farinograph and mixograph test procedures. Mixing curves were also recorded with the test bakery pin mixer. Curves recorded with the pin mixer used a test bakery formulation. The standard farinograph and mixograph tests were also modified by increasing the speed of the mixer and/or using a test bakery formula instead of the flour-water only systems as specified by the standard test procedures.

Strength tests

The standard extensograph and alveograph tests were completed on all samples. The relationship between these test parameters and baking performance was established. The alveograph which is not generally used in Australia, is thought to have an advantage over the extensograph in the way the dough test piece is deformed. Thus emphasis was placed on the improvement of this test. A compression test, based on two other previously published procedures, was evaluated as an alternative.

Baking test

All samples were baked at a range of water levels and mixing times using a response surface methodology design. From these results the mixing time ("bakery mixing time") and the water level ("bakery water absorption") producing the highest scoring loaves were determined. These parameters along with the loaf volume and loaf score were correlated with the physical dough test parameters.

2. Results and discussion

2.1.1 Mixing tests

Initial work on this project on a small sample set (2-6 samples) established the maximum and minimum water levels and mixing times (with respect to peaks on mixing curves) that allows manageable doughs that can be processed. Later a larger set of flour samples (28 samples) was selected for further work. The water level and mixing time ranges selected for test baking was based on this initial work.

The relationship between the farinograph development time and the bakery mixing requirement improved substantially when the speed of the mixer was increased from 60 rpm (standard procedure) to 180 rpm. Higher mixer speeds also resulted in mixing curves with more easily defmed points from which parameters could be measured. Good relationships between the bakery mixing time and the TAP were also obtained with the mixograph and the pin mixer. The incorporation of a test bakery formula into the farinograph or the mixograph tests did not further improve these relationships. Figure 1 shows the correlations between bakery mixing time and the TTP's as determined by the various mixing tests.

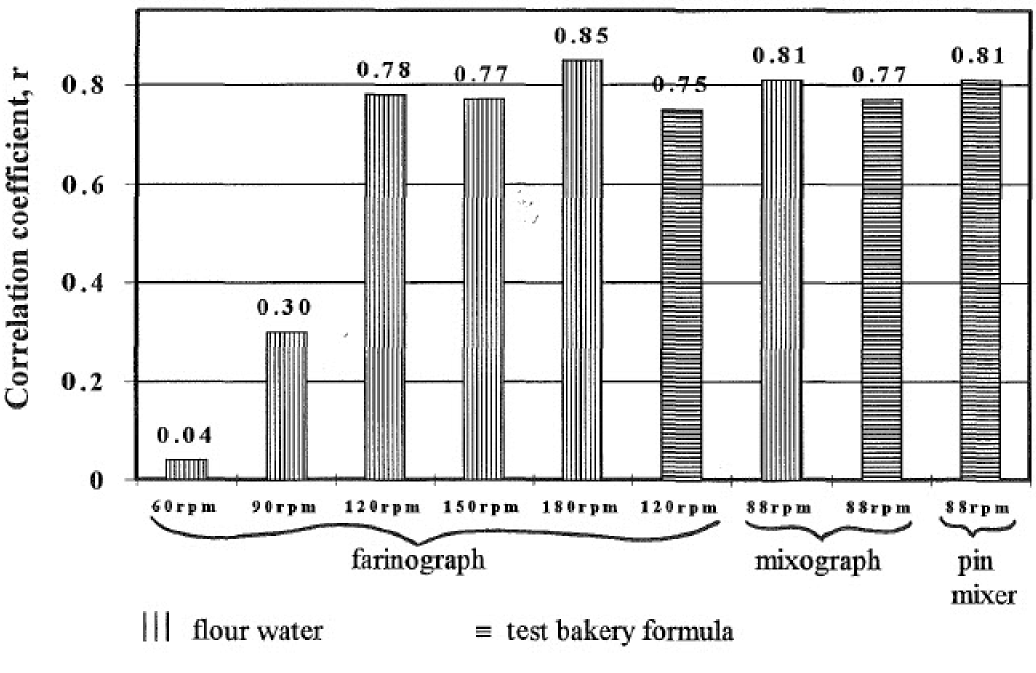

Figure 1 Relationship between the TTP's obtained from the mixing tests and *the bakery mixing time.*

The effect of a test bakery formulation was to increase the TTP. The pin mixer (test bakery formula) gave almost identical TTP's to the *bakery mixing time*. The test bakery formula mixograph gave similar values.

The regression equation for predicting the bakery mixing time from the pin mixer shows it is better to mix beyond the TTP for optimum loaf quality. How far beyond depends both on flour quality and also the practicality of dough temperature and production schedule.

Bakery mixing time = 1.2 (pin mixer TTP) – 34, R^2 = 0.65

This equation shows it is better to mix beyond the time to peak for mixing times greater than 170 seconds. The percentage mixing beyond the peak increasing with increasing TTP's.

The mixograph TTP with flour-water (standard method) correlated very well to the test bakery formula mixograph TTP (r=0.97***) (Fig. 2). Incorporating a test bakery formula into the test did not provide any advantage in relating the TTP to the *bakery mixing time*. This however supports the standard mixograph procedure as a sound procedure for predicting the *bakery mixing time* from a small flour sample.

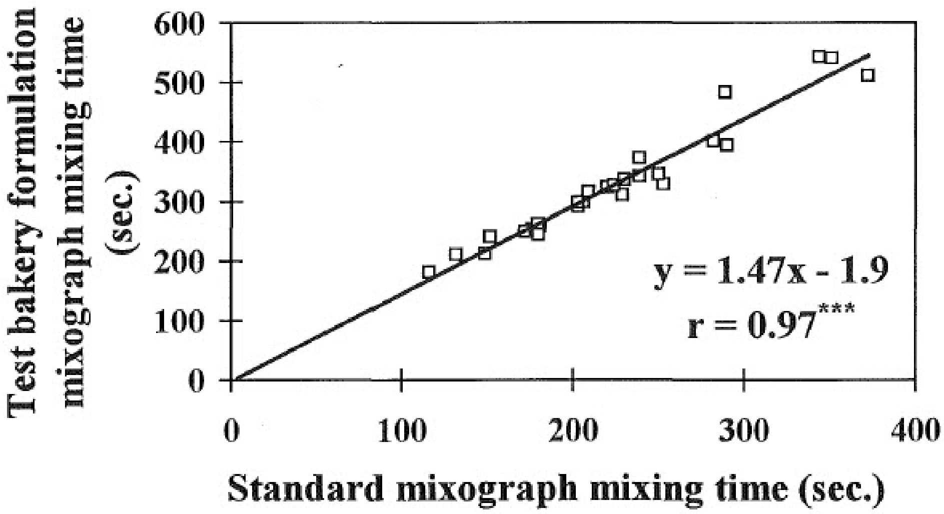

Figure 2 Relationship between the mixograph mixing time with and without test baking formulation.

Some results from this work were presented as a poster paper entitled *Improved relationships between laboratory mixing tests and test bakery mixing requirement* at the 45th RACI Cereal Chemistry Conference, 1995. This poster won an award for best visual presentation, and was short listed in other categories including valuable content.

2.1.2 Work input

The energy or work input in mixing dough to peak consistency was also investigated as a means of identifying the optimum mixing requirement. The work input as defined by the area under the curve was closely related to the mixing time, decreasing with increasing work input rate (mixer speed). Thus different flours and mixers require mixing to different work inputs. The dough development can be judged from the work input if the flour, mixer and formula remain constant. It is more valuable to judge dough development by monitoring the peak on a mixing curve, rather than work input, if the behaviour of a mixer, flour or formula is unknown.

2.1.3 Easymix software

This project identified the need for a system which will record and analyse mixing curves in real time. A requirement of this system was for the software to operate in the windows environment and be capable of running on any computer without modification. A second requirement was to be able to have any mixer linked to the system without any modifications to the mixer. Hence, this project initiated the development of *"Easymix"* software by the Bread Research Institute (BRI). This system for monitoring mixing curves has been subsequently used in a commercial application in a plant bakery. The *Easymix* system is now a product marketed by the BRI. Although the system was **not** developed as part of this project, the need for such a system was initiated through this project.

2.1.4 Predicting the bakery water absorption

Although the standard farinograph test was not useful as far as mixing time is concerned, the farinograph water absorption (FWA) was of some value. The correlation between the FWA and the bakery water absorption (BWA) was good (r=0.80***) (Fig. 3).

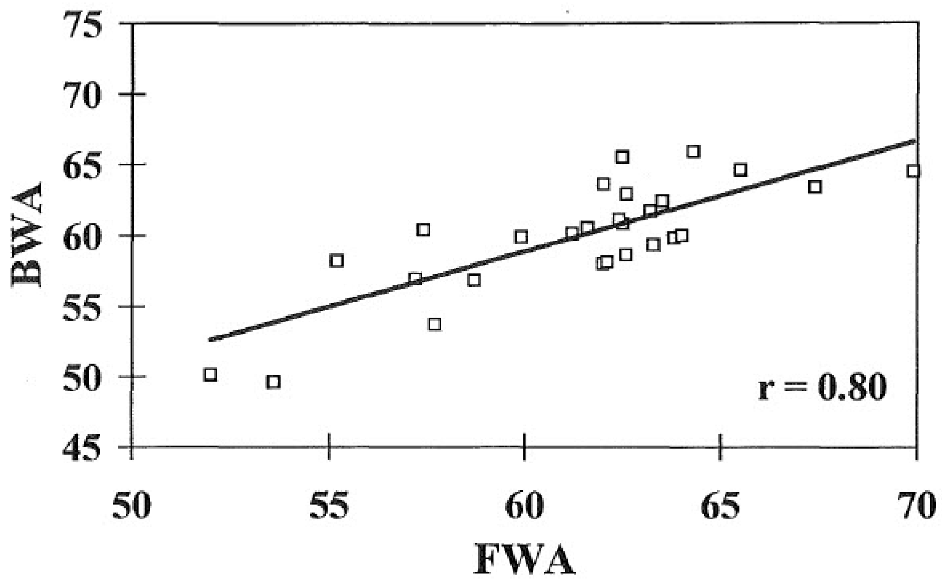

Figure 3 The correlation between the farinograph water absorption (FWA) and the bakery water absorption (BWA).

The farinograph water absorption also correlated well with the peak resistance (PR) (Fig.4) and the maximum bandwidth of the mixograph. Correlating the above mixograph parameters directly with the BWA, the relationships were not as good. However, the above results suggests the potential to measure dough consistency using the mixograph, and because of the excellent relationship of the mixograph TTP to the bakery mixing time, the standard farinograph test may be expendable, especially in breeding programs.

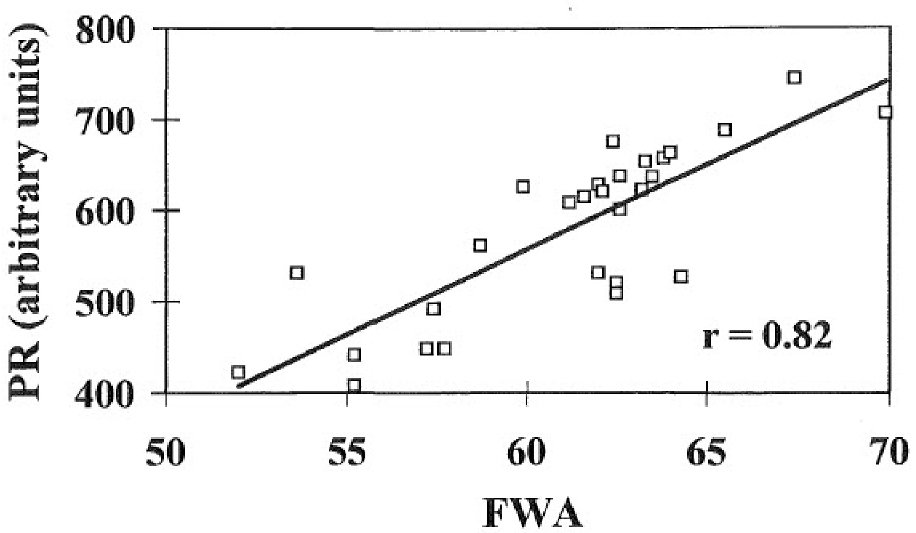

Figure 4 Correlation between the farinograph water absorption (FWA) and the mixograph peak resistance (PR).

2.1.5 Commercial scale equipment

The effect of dough development and water addition on bread quality was investigated using commercial scale equipment in the Bread Research Institute's pilot bakery. The Kemper spiral (medium intensity) and Tweedy (high speed) mixers were used in this study. This work also examined crumb firmness and rate of firming as measured objectively with the Inston universal testing machine. This study showed consistently better loaf volume and loaf score as the mixing input was increased. Undermixed doughs had markedly reduced volumes and scores. This clearly showed the threat to bread quality of undermixing in the absence of bromate. Longer mixing also produced softer crumb. The rate of staling was not affected by mixing treatment. Higher water addition did not significantly affect loaf quality, but did produce softer crumb. Where softer bread is a desirable feature, increased water addition also increases bakery yield. This work emphasised the necessity for full dough development in the mixer. This reinforces the issues facing wheat breeders to develop wheats which mix more rapidly.

Data was also developed from this study to express the impact of water addition on bread yield.

2.2 Strength tests

The extensograph (common in Australia) proved more valuable than the alveograph (common in European countries). A modification to the alveograph dough making procedure was attempted to improve the test. This was not successful (reported to 1993 RACI Cereal Chemistry Conference).

The extensograph height and length of curve were both equally correlated to loaf quality (r=0.66*** and r=0.68*** respectively). The length of the alveograph curve was slightly better correlated to loaf quality than was the height of the alveograph curve as determined following the standard procedure (r=0.67*** and r=0.54** respectively). These results show that not only the strength (height of curve), but the extensibility (length of curve) is also important for good loaf quality. Since the height of the curve is not correlated to the length of the curve for either the extensograph or the alveograph tests, by using both the height and length, a better prediction of the loaf quality may be obtained. The following equation shows the model for predicting loaf quality from the extensograph height and length:

$$\begin{cases} \text{Loaf Quality} = 0.0267\,(\text{extensograph height (BU)}) \\ \qquad + 1.156(\text{extensograph length (cm)}) + 39 \\ R^2 = 0.71 \end{cases}$$

A compression test was developed to compete with the extensograph in providing useful information. It has been shown by previous workers that the relaxation time as measured by a dough under a compressive load had potential in relating to baking performance. Our test produced promising results, but further work is required in developing the compression test. Other methods of measuring rheological properties or the deformation behaviour of dough should be investigated, and relating test parameters from such tests to baking performance.

2.2.1 Relationship between dough strength and mixing requirement

One of the aims of this project was to determine if dough strength (as measured by extensograph resistance) was directly related to mixing requirement. The alveograph was also investigated as this instrument is used to measure strength in other countries.

There was significant correlation between dough strength as measured by the standard extensograph or alveograph tests, and the bakery mixing requirement, as determined from test baking. Figure 5 shows that there is a strong relationship between the extensograph maximum resistance (height of curve) and the *bakery mixing time* which produced the maximum loaf volume. There was no correlation between the length of either the extensograph or the alveograph curves and the bakery mixing requirement.

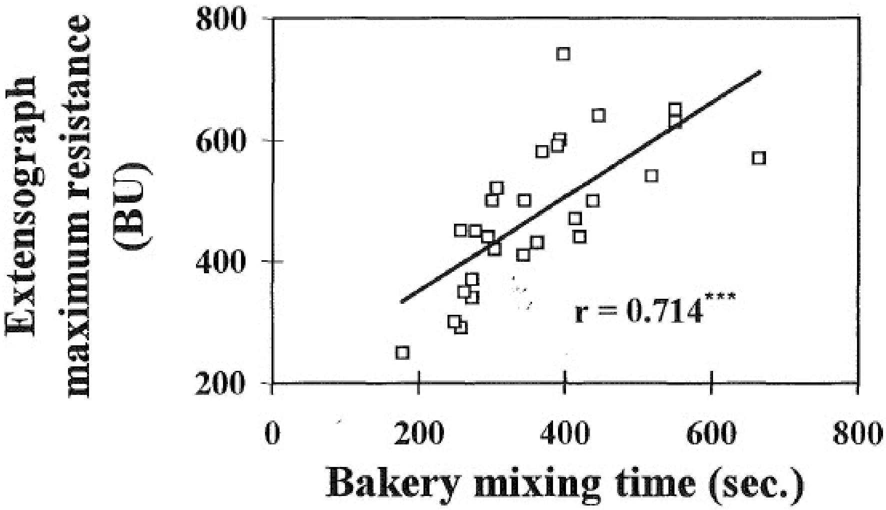

Figure 5 Relationship between the extensograph maximum resistance and the bakery mixing time.

Since the mixograph, pin mixer and the farinograph (at the higher mixing speeds) correlated well to the bakery mixing time, the relationship between the extensograph/alveograph parameters and the mixing test parameters was examined. The extensograph height correlated well to the mixograph TTP (r=0.78***) and the pin mixer TTP (r=0.57***). The alveograph height also correlated to the mixograph and the pin mixer TTP, but this correlation was not as strong (r=0.44* and r=0.38* respectively). The length of the extensograph or alveograph curves generally showed no relationship to the TTP. However, the pin mixer TTP showed a weak correlation to the extensograph or alveograph length of curve (r=-0.40* and r=-0.42* respectively). The farinograph TTP generally correlated to the extensograph or the alveograph TTP's, particularly at the higher farinograph mixer speeds. Figure 6 shows the relationship between the extensograph maximum resistance and the farinograph TTP at 120 rpm.

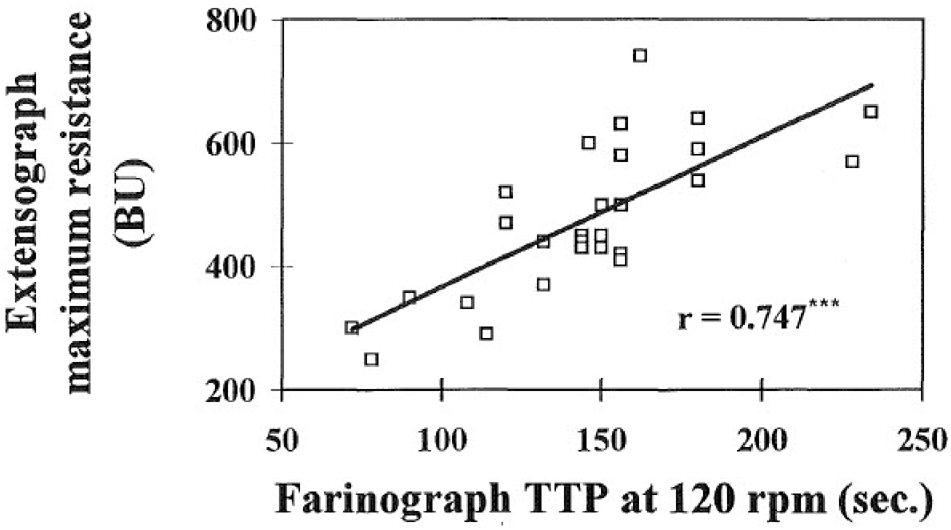

Figure 6 Relationship between the extensograph maximum resistance and the farinograph time to peak (TTP) at 120 rpm.

2.3 Rate of Work Input

A separate study was conducted on three flours (Sunco, Banks and Machete) to investigate the effect of work input rate (mixer speed) on loaf quality. All mixing was done in a 300g farinograph bowl at mixer speeds of 60, 100, 140 and 180 rpm. The work input in mixing doughs to peak resistance decreased with increasing mixer speed. There was a significant increase in loaf quality when the speed of the mixer was increased from 60 to 100 rpm, then a gradual increase from 100 to 180 rpm. Figure 7 shows the loaf score at the different mixer speeds for each variety.

This indicates the need for a critical rate of work input for preparation of bread doughs. Results for Machete suggest that this rate of work input may vary between varieties.

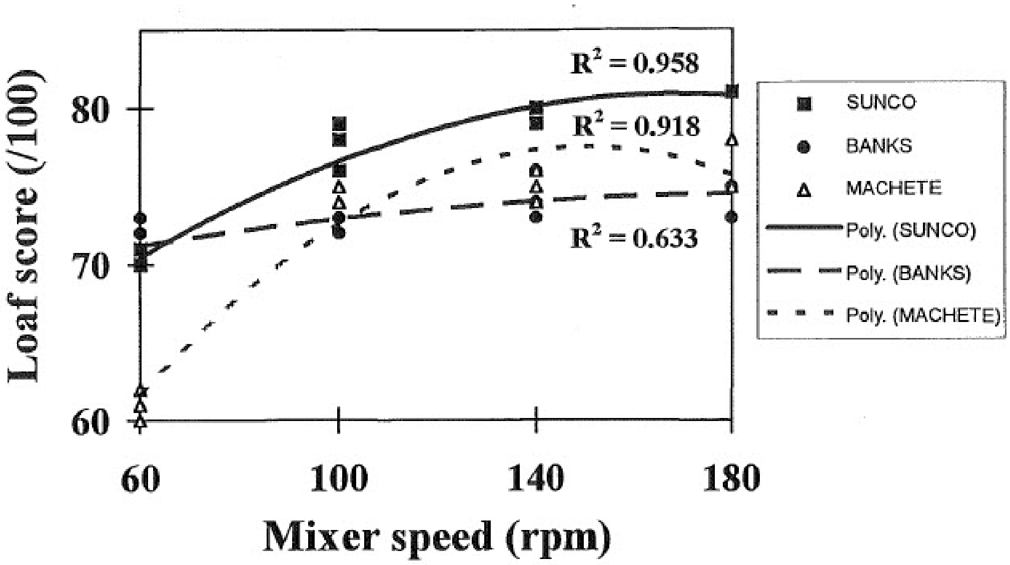

Figure 7 The effect of mixer speed on the loaf score for Sunco (■), Banks (●) and Machete (△).

Industry Implications

1. Results from this study have improved dough mixing in Australian bakeries which has reduced processing problems experienced with strong wheats.
2. Many flour milling companies have adopted new test scale mixing methods to improve their quality systems resulting from this work.
3. Using tests which more accurately predict mixing requirement, strength and extensibility requirements will assist wheat breeders to effectively select for pan bread production and allow flour millers to blend to meet specific requirements.
4. A key selling feature of wheat to world markets is dough strength. A greater understanding of the relationship between dough strength and baking performance will assist flour millers, grain marketers and breeding programs.

Benefits and Costs

Better selection of flour from tests that better reflect the production methods used will result in higher quality bread for the consumer at reduced costs to the industry. Tests that better predict end product performance will help maintain Australia's reputation for producing superior prime hard grades of wheat.