



QUALITY WHEAT CRC PROJECT REPORT

Program 2

Prediction of the dough properties of blended flours based on variety mix

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Prediction of the dough properties of blended flours based on variety mix

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Summary

Tables are provided in this report as a practical aid for predicting the outcome of blending wheat or flour lots with respect to dough quality, depending on the variety mix involved. It assumes that the dough qualities of the components have already been determined, and that the results will be used to design blends that will achieve given specifications. When making these calculations, it may not be valid to simply average the quality values, since the relationships are not linearly related in some cases.

Our research has shown that varietal identity can be used to indicate how best to carry out a blending strategy. Accordingly, wheats that are currently grown in Australia have been characterised for their "blending compatibility". These varieties are arranged in Tables 1 and 2 according to their similarity of glutenin-subunit composition. This aspect of varietal identity is now realised to be a major factor determining the outcome of the blending process. Table 1 (next page) arranges sub-sets of varieties according to states. Table 2 provides a more complete list of wheats currently-grown in Australia, together with their glutenin-subunit compositions.

The mixing of grain or flour of varieties that are close together in the table is likely to provide blending outcomes that are linearly related, with respect to dough properties, because they are similar in glutenin-subunit composition. On the other hand, mixing grain or flour of varieties that are distant from one another in the table is likely to provide blending outcomes that are not linearly related, possibly providing unexpected outcomes in the final blend.

This is an interim report, containing provisional recommendations for trial; research is continuing towards the aim of providing a more comprehensive guide to predicting the outcome of blending. Feedback on the results of trialing these recommendations would be appreciated by the authors.

Table 1. A genetic basis for predicting the dough quality of blends

To use this table, first select the column for your state. Then find the varieties that are to be mixed. Varieties that are vertically distant from one another in the list are likely to give unexpected (non-linear) relationships for dough properties when mixed. Results are most likely to be non-linear when blending varieties from the upper and lower halves of this table.

Qld – NSW	Vic	SA	WA
Cunningham	Janz	Janz	Carnamah
Sunco	Meering	Aroona	Aroona
Sunvale	Ouyen	Eradu	Eradu
Batavia		Machete	Machete
Janz		Blade	Blade
Sunland			
H45			
Sunbri			
Hartog	Dollarbird	Halberd	Perenjori
Sunstate	Halberd	Spear	Amery
Dollarbird	Barunga	Barunga	Wilgoyne
Diamondbird	Frame	Frame	Halberd
Sunbrook		Stiletto	Spear
Suneca			Kalannie
Sunlin			Stiletto

Introduction

Blending is commonly used by industry to achieve quality specifications for wheat and flour. Furthermore, the blending of grain with diverse quality attributes can be used to achieve improved quality and market value compared to the original lots of grain. Success in the blending process depends first on knowing the quality characteristics of the components, and then on various practical factors, particularly difficulties associated with sampling and mixing. However, a major source of uncertainty has been the prediction of quality attributes, such as dough properties, after blending. Such quality attributes have long been acknowledged to be non-linear in their blending relationships.

Prediction of the outcome of blending is a relatively simple task when formulating combined grain lots with respect to composition (e.g. protein content), because the relationships involved are linear. However, blending to achieve a specific target for other quality characteristics (e.g. dough properties) is difficult, because of the non-linearity of relationships involving such characteristics (Simmons and Sutton, 1997; Bekes *et al.*, 1999). This is a common problem in flour milling, where blending is usual practice either before or after milling, for achieving specific quality targets.

Table 2. Current Australian wheat varieties, showing their glutenin-subunit alleles, for use as a basis in predicting the dough-quality blends of different grain or flour samples. Varieties with similar glutenin alleles are placed close together in the table, indicating that these would be expected to give linearly predicted dough properties. Varieties that are distant from one another in the table are likely to give non-linear relationships for dough properties when mixed. Gene designations for the HMW and LMW subunits are shown, respectively, as *Glu-1* and *Glu-3* for each of the three wheat genomes, namely A, B and D.

Variety	<i>Glu-A1</i>	<i>Glu-B1</i>	<i>Glu-D1</i>	<i>Glu-A3</i>	<i>Glu-B3</i>	<i>Glu-D3</i>
Cunningham	<i>a</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>b</i>
Sunco	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Sunvale	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Pelsart	<i>a</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>b</i>
Batavia	<i>a</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>c</i>
Janz	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Sunland	<i>a</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>b</i>
H45	<i>a</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>h</i>	<i>b</i>
Sunbri	<i>a</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Meering	<i>b</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Ouyen	<i>b</i>	<i>b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>b</i>
Perouse	<i>b</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Tasman	<i>b</i>	<i>b</i>	<i>a</i>	<i>b</i>	<i>d</i>	<i>a</i>
Condor	<i>c,b</i>	<i>b</i>	<i>a</i>	<i>c,b</i>	<i>b</i>	<i>b</i>
Carnamah	<i>b</i>	<i>c</i>	<i>a</i>	<i>c</i>	<i>d</i>	<i>c</i>
Aroona	<i>a</i>	<i>c,b</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>c</i>
Eradu	<i>a</i>	<i>i</i>	<i>a</i>	<i>c</i>	<i>b</i>	<i>b</i>
Machete	<i>b</i>	<i>i</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Blade	<i>b</i>	<i>i</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Kite	<i>b</i>	<i>i</i>	<i>a</i>	<i>e</i>	<i>b</i>	<i>b</i>
Miskle	<i>b</i>	<i>i,b</i>	<i>a</i>	<i>b</i>	<i>b</i>	<i>b</i>
Meteor	<i>b,a</i>	<i>i,b</i>	<i>a,d</i>	<i>b,e</i>	<i>b</i>	<i>b</i>
Perenjori	<i>b</i>	<i>i</i>	<i>a,b</i>	<i>d</i>	<i>b</i>	<i>a</i>
Amery	<i>b</i>	<i>i</i>	<i>c</i>	<i>e</i>	<i>b</i>	<i>b</i>
Hartog	<i>a</i>	<i>i</i>	<i>d</i>	<i>b</i>	<i>h</i>	<i>e</i>
Sunstate	<i>a</i>	<i>i</i>	<i>d</i>	<i>b</i>	<i>h</i>	<i>e?</i>
Dollarbird	<i>a</i>	<i>i</i>	<i>d</i>	<i>b</i>	<i>h</i>	<i>b</i>
Diamondbird	<i>a</i>	<i>i</i>	<i>d</i>	<i>b</i>	<i>h</i>	<i>b</i>
Sunbrook	<i>a</i>	<i>i</i>	<i>d</i>	<i>b,d</i>	<i>h</i>	<i>b</i>
Suneca	<i>a</i>	<i>i</i>	<i>d</i>	<i>d</i>	<i>h</i>	<i>e?</i>
Rowan	<i>a</i>	<i>i</i>	<i>d</i>	<i>c</i>	<i>h</i>	<i>e?</i>
Wilgoyne	<i>b</i>	<i>i</i>	<i>d</i>	<i>d</i>	<i>h</i>	<i>b?</i>
Silverstar	<i>a</i>	<i>i</i>	<i>d,a</i>	<i>b,c</i>	<i>h</i>	<i>b</i>
Mercury	<i>b</i>	<i>d</i>	<i>d</i>	<i>e</i>	<i>b</i>	<i>b</i>
Halberd	<i>a</i>	<i>c,e</i>	<i>d</i>	<i>e</i>	<i>c</i>	<i>c</i>
Spear	<i>a</i>	<i>c</i>	<i>d</i>	<i>c</i>	<i>h</i>	<i>c</i>
Kalannie	<i>b,a</i>	<i>c</i>	<i>d,a</i>	<i>b,c</i>	<i>b</i>	<i>b,c</i>
Barunga	<i>a</i>	<i>b</i>	<i>d</i>	<i>c</i>	<i>b</i>	<i>c</i>
Frame	<i>a</i>	<i>b</i>	<i>d</i>	<i>c</i>	<i>h</i>	<i>c</i>
Stiletto	<i>a</i>	<i>c</i>	<i>d</i>	<i>c</i>	<i>h</i>	<i>c</i>
Sunlin	<i>b</i>	<i>i</i>	<i>a</i>	<i>d</i>	<i>b</i>	<i>b</i>

This report provides a guide to the identification of combinations of varieties (Tables 1 and 2) which are more (or less) likely to provide anomalous outcomes with respect to dough properties as a result of blending. The basis of this varietal compatibility (or lack of it) is genetic constitution with respect to glutenin subunits (listed in Table 2).

Prediction of composition for blended samples

Aspects of grain composition can be simply calculated, following blending, as the arithmetic average of the composition of the components, according to their proportions in the mix. Examples:

- Equal amounts of grain with 10% and 12% protein content are mixed. The resulting blend has 11% protein.
- Flour stream A (10% protein) is gristed with Flour stream B (12% protein) in the proportions of 1 of A to 4 of B. The resulting mix has a protein content of $(1 \times 10\% + 4 \times 12\%) / 5 = 11.6\%$ protein.
- Three grain samples (10%, 11% and 12% protein) are mixed in the proportions 1:2:3, respectively. The resulting blend has a final protein content of $(1 \times 10\% + 2 \times 11\% + 3 \times 12\% / 6) = 11.3\%$ protein.

Prediction of quality for blended samples

In the case of compositional attributes, outcomes may be determined mathematically (as shown in the examples above for protein content), or using simple linear graphs. This is not so, for many other quality-based attributes, for which relationships are not linear. Such attributes include ...

- Dough properties
 - extensibility,
 - time to peak dough development,
 - resistance to mixing.

The use of the Table 2 information applies primarily to dough properties such as these.

- Water absorption
- Product quality
 - baking quality (loaf volume)
 - crumb texture
 - noodle quality

The Table 2 information probably applies to the above attributes of water absorption and product quality, because of the relevance of dough quality, but these aspects are still being studied.

- Enzyme-related attributes
 - Falling Number
- Starch characteristics
 - RVA peak consistency
 - time to peak

Tables 1 and 2 do not have any relevance to enzymes or starch quality, because these properties are not related to glutenin-subunit composition. The extent to which relationships may be predicted is still being studied for some other attributes, such as noodle colour and texture.

Dough properties

Examples of the non-linear character of dough-quality relationships are provided in Figure 1. These experiments involved the mixing of pairs of flour samples to form blends ranging from 100% of one to 100% of the other, and testing the dough properties of the resulting blends. The examples shown in Figure 1 are a few of hundreds of blends that have been tested. Each of the four pairs is different in Table 2.

The time to reach peak resistance to mixing in the Mixograph (shown as "mixing time" in Figure 1) was linearly related to the proportions of the two component flours in some cases (upper left section of Figure 1). In the other three cases, there was a progressive deviation from linearity (other parts of Figure 1).

The extent of non-linear behaviour was closely related to the dissimilarity of the two flours with respect to their HMW glutenin-subunit composition (indicated by the set of glutenin subunit numbers for each component, shown within each square). The pair of parent flours illustrated in the upper left part of Figure 1 had identical subunit compositions; this produced almost linear mixing behaviour.

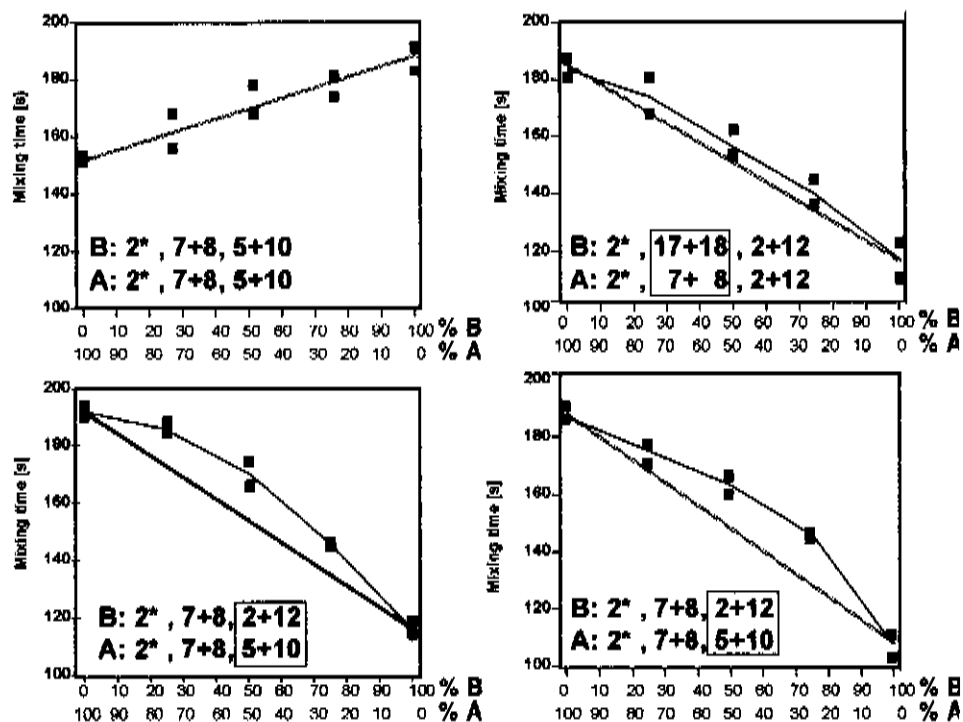


Figure 1. Variations in time to peak dough development in the Mixograph for four pairs of blends of flour samples having the HMW glutenin subunit compositions shown. A straight line is included connecting the values for the pure samples, for comparison with the lines connecting the experimental points.

The progressive departure from linearity for the other examples in Figure 1 is associated with increasingly greater differences in HMW-subunit composition, this being judged partly according to the *Glu-1* score system of Payne (1987), shown in Table 3.

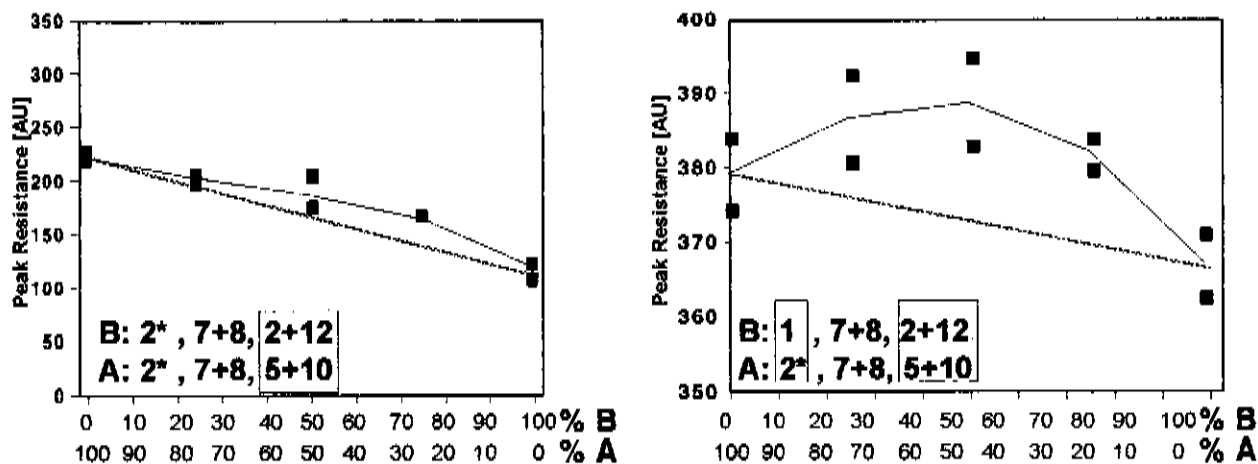


Figure 2. Variations in peak height at maximum resistance in the Mixograph for two pairs of flour samples (different varieties), having the glutenin-subunit compositions shown.

A similar range of behaviour was found when the flour blends were analysed for other aspects of dough quality, such as peak resistance and dough breakdown in the Mixograph, Farinograph dough-development time and water absorption, and extensibility. As examples, Figure 2 illustrates this behaviour for peak resistance in the Mixograph, the degree of divergence from linearity again being related to the extent of difference in HMW-subunit composition for the pairs of varieties being blended.

Practical use of the variety table

When considering the blending of wheat or flour consignments, knowledge of the varieties involved is of great potential value. Compare the distances between the varieties involved in Tables 1 or 2. If they are close together (that is, they have similar glutenin alleles), the resulting blend is likely to have dough properties intermediate between those of the original flours, and arithmetic averaging of properties is reasonably valid (using calculations similar to those provided in the examples above for protein content).

If the varieties involved are distant in Table 2, thus with different allelic constitutions, it will probably be less valid to calculate the dough properties of the blends, especially if each of the different varieties is mixed in significant proportions (e.g. over a third of each). In this case, either be wary about attempting to predict the outcome of the blending process, or ensure that these dissimilar varieties are incorporated at lower levels (e.g. less than 20% of each).

Making simpler versions of Table 2

Table 2 lists varieties relevant to all parts of Australia. For local requirements, one of the columns of Table 1 may be more relevant. Alternatively, a better version of the table may be prepared, containing only those varieties that are encountered locally, by eliminating all the varieties from Table 2 that are not relevant. Assistance in doing this can be provided by the authors, if necessary. For practical purposes, the information about glutenin alleles could

also be removed, but the following section is provided as background reading on the significance of glutenin composition.

The subunits of glutenin

A better understanding of Table 2 is provided by considering the functional properties of the glutenin proteins in dough. About half of the proteins making up the gluten of dough are gliadins - smaller monomeric proteins that appear to act as lubricants in dough. The other half of the protein is glutenin – a collection of disulfide-crosslinked polypeptides with a range of sizes, measuring up to tens of thousands of Daltons in molecular weight. They probably include some of the largest protein molecules in nature.

The individual polypeptides (“subunits” or protein chains) that make up glutenin are divided into two classes ...

- **the high-molecular-weight (HMW) subunits,**
 - numbered as subunits 1, 2, 3, ...,
 - making up about one quarter of glutenin,
 - synthesised under the control of the *Glu-1* genes, which are denoted by lower-case letters (*a, b, c, ...*). These are the letters shown in Tables 1 and 2.
- **the low-molecular-weight (LMW) subunits,**
 - not with numbered subunits,
 - making up about three quarters of glutenin,
 - synthesised under the control of the *Glu-3* genes, which are also indicated by lower-case letters (*a, b, c, ...*). See Tables 1 and 2.

The HMW subunits often appear as pairs (e.g. 5 with 10, 2 +12, and 17 + 18), because their synthesis is controlled by corresponding pairs of genes at the *Glu-1* locus. This is indicated in Table 3, which lists the correspondence between the subunit numbers and the gene designations (alleles). For example, subunit 1 is synthesised under the control of allele *a* (also designated as *Glu-A1a*), and subunits 5 and 10, under the control of the allele *Glu-D1d*.

Table 3. *Glu-1* dough quality scores assigned to HMW glutenin subunits and corresponding alleles, according to Payne (1987). A high score (maximum of 10) indicates a prediction of strong dough properties.

<i>Glu-1</i> Score	<i>Glu-A1</i>		<i>Glu-B1</i>		<i>Glu-D1</i>	
	Allele	Subunit	Allele	Subunit	Allele	Subunit
4					<i>d</i>	5+10
3	<i>a</i>	1	<i>i</i>	17+18		
3	<i>b</i>	2*	<i>b</i>	7+8		
3			<i>f</i>	13+16		
2					<i>a</i>	2+12
2					<i>b</i>	3+12
1	<i>c</i>	Null	<i>a</i>	7	<i>c</i>	4+12
1			<i>d</i>	6+8		
1			<i>e</i>	20		

Further studies have provided estimates of the relative contributions of the various HMW subunits of glutenin to dough properties. These contributions are indicated in Table 3 as score numbers. The total score for a variety is based on the set of its three HMW subunits as the sum of the contribution from each subunit (one for each of the three genomes of wheat – A, B and D).

For example, a score of 10 (highest possible) would be obtained for alleles *a*, *i*, and *d* (in each of the A, B and D genomes, corresponding to protein subunits 1, 17+18, and 5+10), derived from individual scores of 3, 3 and 4, respectively, according to Table 3. These rankings, indicating the importance of the subunits, are also relevant to the degree of difference in blending, and they are reflected in the relative ordering of Australian varieties in Table 2.

Blending grain versus flour

A further complication is introduced when considering the blending of wheat samples before milling, compared to the simpler case of blending flour streams. In some cases, the effect of the added factor of milling has been a greater departure from linearity when the grain is blended before milling than there is for the blending of the flour samples. In other cases, it has been the reverse of this. Examples of both cases are provided in Figure 3.

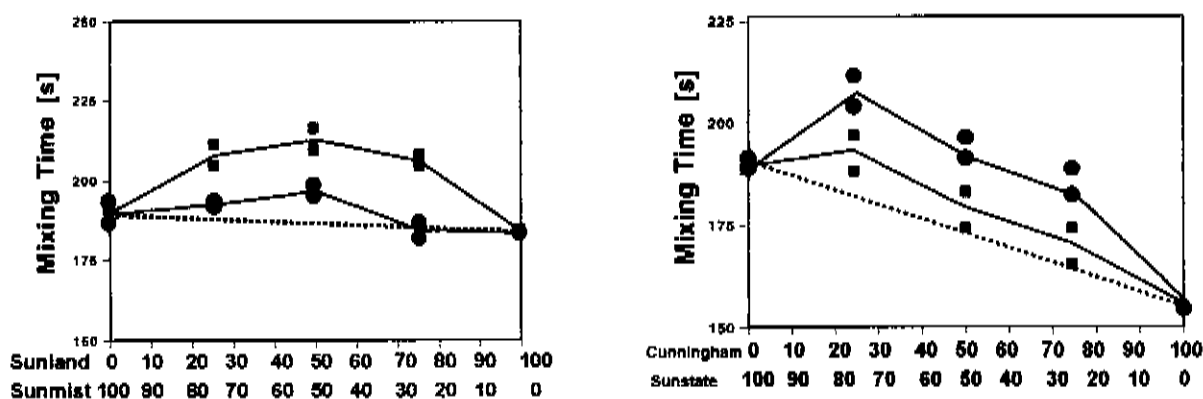


Figure 3. Variations in time to peak dough development in the Mixograph for two pairs of blends of wheat samples (squares), compared to the cases of flour samples (circles) being blended after milling.

It is likely that this differential behaviour for grain and flour blending is also related to the subunit composition of the glutenin subunits. This is probably because of differences in the distribution of gluten proteins carried into the flour during the milling process. The distribution of endosperm between flour and bran depends primarily on milling yield, and thus on grain hardness and on grain-size distribution.

The effect of the milling step is an additional factor that must be taken into account in developing a mathematical model for routine use by industry – the objective of this ongoing research. The tables of varieties (Tables 1 and 2) are offered as an interim tool to assist in practical blending situations.

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