Conclusions

- Crop & Food Research's 125 g MDD mixers are good predictors of industrial scale work input requirement when operated at normal speed (150rpm).
- Mixer peak torque, mixing time, mixer blade turns and work input all depend on the mixing speed. Above about 150 rpm the pattern is the same for the 125 g and 10 g mixers - a steady increase in work input requirement with mixing speed. Below 150 rpm the 125 g mixer requires more mixer blade turns, and hence a higher work input to develop the dough than the10 g mixer.
- Overall the 10 g mixer requires slightly less work to develop dough than the 125 g mixer.
- Increased mixing speed can make mixing times very short but at the expense of increased work input requirement.

Crop & Food Research have recently purchased a modified ECS35 (15 kg flour) small industrial mixer so that we can investigate the effect of mixing speed on industrial mixers. We have made extensive HPLC measurements of protein changes in doughs during mixing on laboratory mixers and we intend to extend this to industrial mixers.

Acknowledgement

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RESEARCH BULLETIN

Flour milling and baking

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Bread dough development

- the effect of mixer size and speed

The mechanical dough development process used by the majority of New Zealand plant bakeries is characterized by the need to develop bread dough using high speed or high energy mixing. Most have Tweedy or similar mixers (or developers) that mix 100-200 kg of flour at a time. Traditionally, dough was developed to work inputs of about 11 Wh/kg in less than 4 minutes.

Flour for bread production is the culmination of a long process that starts with plant breeding and ends with milling. At many steps in this process the product is tested to ensure that the flour produced will be suitable for bread making. This testing is usually done with small dough mixers but these must be able to accurately simulate large industrial mixers, otherwise the flour produced will be unsuitable for industrial bread making. There is almost no published information on how well laboratory mixers predict industrial bread mixing requirements. Crop & Food Research staff have many years of experience in this area and see two important challenges and industry needs. The first is to measure the optimum work input in industrial mixers. Secondly, the results from mixers of different size need to be compared. This bulletin explains the background of this work, current understanding and the direction of future research.

Features of the bread dough mixing curve

When bread dough is mixed in a dough mixer, or even by hand, it undergoes a complex series of chemical reactions. These can be detected as changes in physical properties when dough changes from being inextensible and weak, to smooth, extensible and strong, finally becoming very extensible, weak and sticky. The baking properties also change. The best bread is usually produced from dough mixed to its strongest point or just beyond.

These physical changes are typically measured by mixing 30-300 g flour in small laboratory mixers and recording the force on the mixing blades as a mixing curve. The characteristic feature of these mixing curves is that they rise to a peak, the 'optimum' and then decrease again. The energy required to mix the dough to peak height is a measure of the work input requirement of the dough. The height of the peak indicates the dough consistency or 'feel'. Normally the amount of water added to dough is adjusted to give a mixing curve of a standard height which is equivalent to the optimum consistency for dough handling.

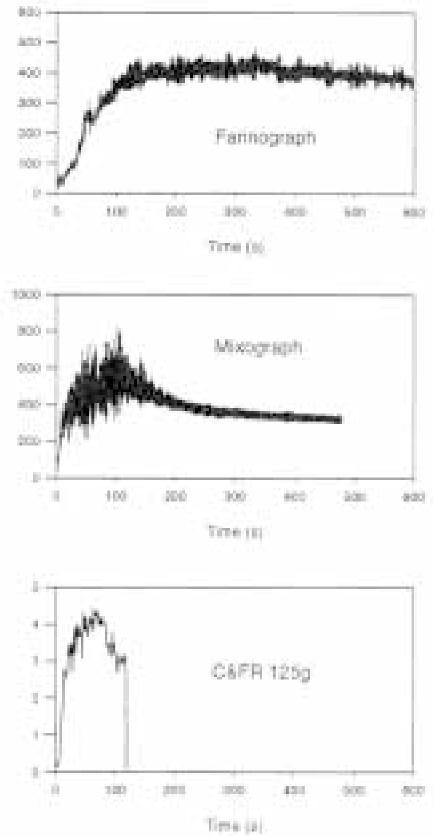

Figure 1: Mixing curves for Farinograph, Mixograph and C&FR (mixer) laboratory mixers.

The Farinograph and Mixograph are the most commonly used laboratory dough mixers worldwide. As shown in Figure 1, the shapes of the curves for the three mixers are quite different, indicating differences in the type of mixing. The times to optimum are also very different, varying from about 300 seconds for the Farinograph to 70 s for the C&FR 125 g mixer.

Finding work input optima for industrial dough developers

A major problem for industrial bakeries is that industrial Tweedy and other similar mixers do not produce a typical mixing curve with a clear optimum. As dough develops in a Tweedy-type mixer, the amount of contact between the dough and the bowl and rotor changes so that the load on the motor (power) stays relatively constant, as shown in Figure 2. Therefore, it is not possible to determine the optimum amount of dough development from Tweedy-type mixing curves.

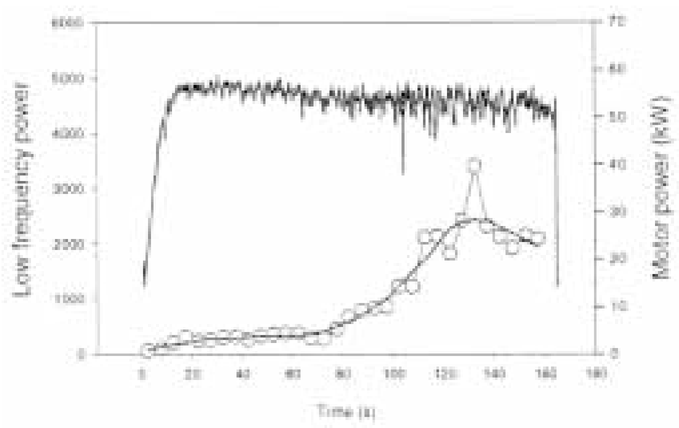

Figure 2: Mixer motor power (—) and dough probe (o) low frequency power.

Crop & Food Research and other researchers are looking for methods of measuring optimum work input in these mixers. On-line measurements, such as the dough probe and NIR reflectance can be used to measure the amount of dough development while a dough is mixing. The dough probe (Wilson et al. 1997) extends a short distance through the bowl wall into the bowl. The probe measures the force exerted by the dough during mixing, records it and analyses the force data to measure the power at different frequencies. This is used to derive a mixing curve that displays the mixing optimum.

A near infra-red reflectance (NIR) method that is promising but not yet commercially available uses a fibre-optic probe to shine infra-red light on the dough and measure reflected light at several wavelengths. This system detects chemical changes in the dough that are related to dough development (Wesley et al. 1998) and was explained in NZ Flourmilling & Baking Industry Tech News no. 3, 1998.

Researchers at Crop & Food Research and elsewhere are looking at various other methods. The simplest is to bake doughs mixed to a range of work inputs and determine the optimum mixing conditions. Other methods use dough samples taken sequentially through mixing. Stained and sectioned samples can be examined under the microscope to estimate the amount of protein and its distribution. HPLC analysis can be used to measure changes in the distribution of proteins.

Comparing dough development in 125 g laboratory and Tweedy-type industrial mixers

Over a 30 year period, Crop & Food Research (and its predecessors) have developed a series of mixers for testing flour based on the same basic design but mixing 10 g, 50 g, 125 g, and 1 kg of flour. Of these, the 125 g has been used most extensively. As part of Crop & Food Research's government funded work we have shown that the 125 g mixers give good prediction of industrial scale work inputs. Recently we investigated how these measurements depend on mixing speed and mixer size.

A dough probe mounted in a Tweedy-type industrial mixer was used to determine the mixing optimum for 14 flour samples with a range of work inputs. The optima for the same flours were measured on the Crop & Food Research 125 g mixers. The results are shown in Figure 3 where the dotted line indicates perfect agreement. The 125 g mixers gave slightly higher values at normal to high work inputs but lower values at very low work input. The flours are generally ranked similarly for the 125 g and industrial scale mixers.

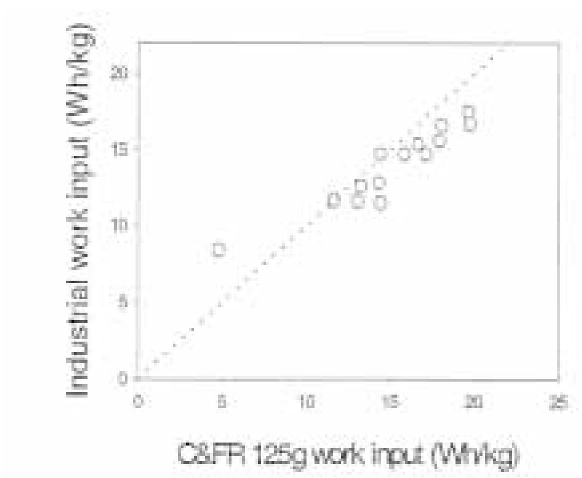

Figure 3: Comparing work inputs measured on industrial Tweedy and 125 g laboratory mixers.

Work input results depend on mixer and speed

When mixing dough on any mixer, one of the important parameters is the mixing speed. Altering the mixing speed changes not only the rate of mixing or rate of work input, but also the dough characteristics. Crop & Food Research has investigated the effect of varying the mixing speed of 125 g and 10 g mixers on weak (low work input-biscuit flour) and bread (high work input) flours. Both types of flour were made into doughs using bread dough formulae.

Peak torque increased with mixing speed for both mixers in exactly the same way (Figure 4).

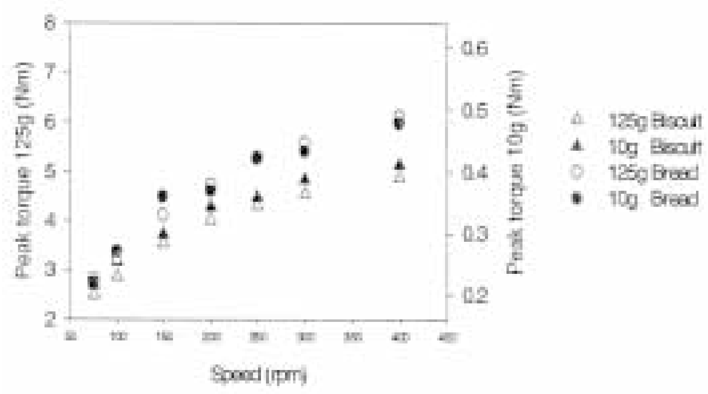

Figure 4: Development of doughs made from bread and biscuit flours in 10 g and 125 g laboratory mixers at different speeds.

As expected, the faster the mixer blades moved, the harder it was to push them through the dough. The optimum number of mixer blade turns required was greater at low speeds than at higher speeds where the value was relatively constant (Figure 5). This effect was, however, more pronounced in the 125 g than 10 g mixers.

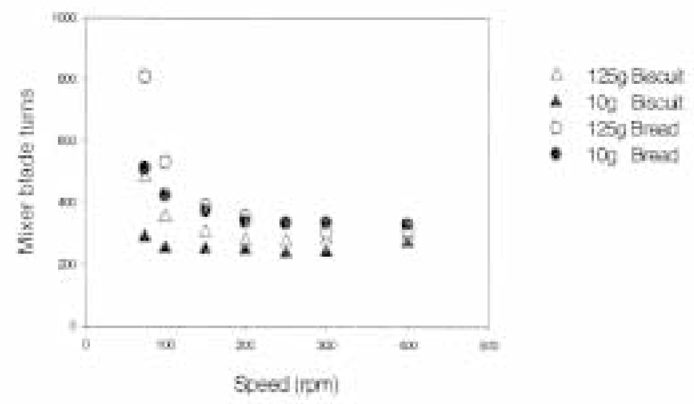

Figure 5: Number of mixer blade turns required to develop biscuit and bread flours in10 g and 125 g mixers.

As the work input is the product of the torque and number of mixer turns, the optimum work input increased dramatically at low speeds for the 125 g mixers and steadily increased at higher speeds (Figure 6). There was good agreement at higher speeds between the 10 g and 125 g mixers but at low speeds the optimum work input on the 10 g mixers did not increase as it did for the 125 g mixers. Overall the 10 g mixer was slightly more efficient than the 125 g mixer, requiring about 1 Wh/kg less energy to develop the dough.

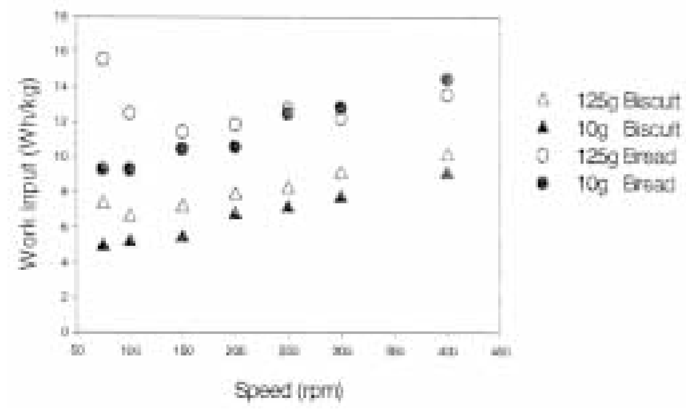

Figure 6: Optimum work inputs required to develop biscuit and bread flours in10 g and 125 g mixers.

For bread flour in the125 g mixer, the lowest optimum work input was achieved by mixing dough at about 150 rpm, the normal speed for these mixers. Mixing dough at 400 rpm increased the work input from 11.6 to 13.5 Wh/kg but decreased mixing time from 152 to 46 seconds. For the 10 g mixer the lowest work input for the bread flour occurred at 75 rpm with a work input of 9.3 Wh/kg and a mixing time of 408 seconds. At 400 rpm the work input was 14.4 Wh/kg and the mixing time was 50 seconds, very similar to the 125 g mixer.

At normal and high speeds (>150 rpm) the 10 g and 125 g mixers give similar results but the 10 g work inputs were slightly lower because fewer mixer blade turns were required to develop the dough. At speeds less than 150 rpm there were large differences in work requirement because the 125 g mixer required many more mixer blade rotations to develop dough than the 10 g mixer.