Assessing the Handleability of Bread Dough

Christine Tock[1], Fred Gates[2], Charles Speirs[2], Gary Tucker[2], Phil Robbins[1], Phil Cox[1]

[1] School of Chemical Engineering, University of Birmingham, Edgbaston, B15 2TT, UK.
2 Campden BRI, Station Road, Chipping Campden, Gloucestershire, GL55 6LD, UK

ABSTRACT

A compression test has been developed whereby the energy per unit area for compression of dough between specified strains is calculated. Doughs with varying softness and stickiness levels were produced. Significant correlations were seen with bakers assessments of both stickiness and softness, although softness showed the strongest correlation.

Doughs produced to the same Farinograph consistency did not give the same softness and stickiness. The compression test could differentiate these doughs.

A significant correlation was seen between the dough handling assessment and compression test results. This suggests that, with further development, the compression test could predict potential difficulties with dough processing.

INTRODUCTION

There is a need, within the baking industry to be able to reliably produce doughs which can be processed with high throughput in mechanised bakeries. Doughs that cannot be processed lead to losses in both time and product. Such losses are of economic concern and there is a desire to be able to assess whether doughs are going to cause problems before these problems occur.

Dobrasczyk stated in 1997 that there was no universal measure for stickiness[1] and this is still the case. Assessment of dough properties is currently commonly performed by a baker assessing the feel of the dough and grading properties such as softness and stickiness. While it is desirable for dough to be soft, stickiness causes real problems in processing. These attributes are therefore scored separately by the baker in an attempt to disentangle these two properties[2].

Assessments like these require a skilled and trained baker and there is a desire to move away from such subjective assessments towards more quantitative instrumental techniques.

The current widely accepted technique for assessing the consistency of dough is by Brabender Farinograph. This is a technique whereby the torque is measured during mixing of the dough and a number of parameters can be obtained from the resulting trace. Peak values are used to find the water addition required to give the same consistency value, usually 600 BU in the UK[3]. There is an assumption that doughs with the same peak consistency value will behave the same way.

Previous work by the author demonstrated a strong correlation between baker's assessment of softness and the energy per unit area of compression for the selection of doughs used[4]. Current work has built on this by using a much wider variety of doughs and is considering the hypothesis that energy per unit area of compression is related to the softness of the dough, as assessed by a baker, which is in turn related to the behaviour of the dough when passed between rollers.

METHOD

Non-yeasted wheat flour doughs were produced from different types of flour, with a range of ingredients and mixing times. This produced doughs with a range of softness and stickiness levels, as assessed by a baker.

In this work, doughs were assessed by three separate techniques; bakers assessments, compression tests and a quantitative assessment of dough handling.

Doughs were mixed using a z-blade mixer and allowed to rest before testing. Quantitative dough handling assessments were carried out after 10 minutes, with a corresponding bakers assessment. Compression tests were performed after a 40 minute rest time, along with bakers assessments.

Bakers assessments were performed by a trained baker and softness and stickiness were assessed separately. Softness was scored on a scale of 1 - 5, firm to soft, where 3 is considered optimum. Stickiness was scored from 0 - 2, with 0, not sticky, being optimum.

Samples were prepared for compression testing by taking a set mass of sample, which was rolled into a ball and then compressed using a StableMicroSytems TA.XT*plus* Texture Analyser.

Compression tests were performed in triplicate. Occasionally an error occurred in the running of the test which was only apparent on analysis. In these cases the invalid result was excluded from the analysis.

The compression test comprised of 5 stages. The first stage is a precompression phase which reduces shape variability. This is followed by a rest phase before the third phase, the compression test, begins. Following compression there is another pause before the final pull-off phase. The third phase, the compression phase, is the focus of this work. During this compression, dough pieces are compressed from an initial strain to a set final strain at a constant rate of 0.2 mm/s.

Image analysis was used to find the radius of the dough piece in contact with the top plate at three key points in the test: start, mid and end of compression. The radius was then modelled over the full duration of the test period. Assuming an axisymmetric dough piece, this allows the contact area to be calculated and thus the stress and also the energy per unit area.

Hencky strain was calculated as shown in Eq. 1, where H is initial sample height and h is sample height. Stress was calculated using the measured force and the contact area calculated from the measured radius (see Eq. 2). Energy per unit area was calculated as the area under a stress – distance curve up to a specified Hencky strain.

$$\varepsilon_h = ln\left(\frac{H}{h}\right) \tag{1}$$

$$\sigma = \frac{F}{A_{contact}} \tag{2}$$

One of the areas in the production process that causes particular problems with sticky doughs is the post-mixing processing and moulding[5] which includes steps such as sheeting. Quantitative assessment of dough handling was based on the behaviour of the dough when passed between sheeting rollers. The dough pieces were passed multiple times between the rollers at decreasing gap widths until the dough could no longer be processed (see Fig. 1). Observations of the appearance of the dough piece and the number of passes achieved were recorded, up to a maximum of 17 passes.

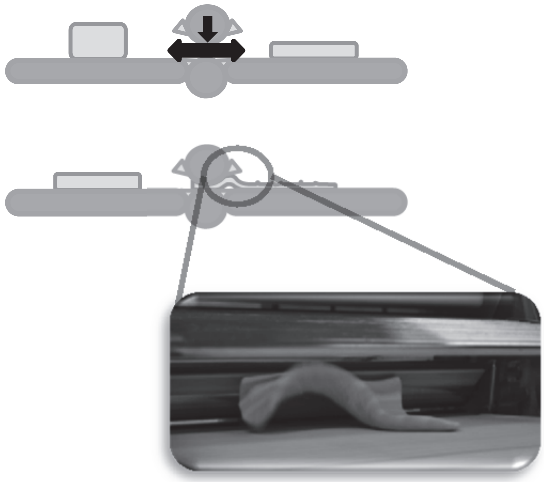

Figure 1. Diagram showing the roller setup and the result of a sticky dough passing through the rollers.

Additionally, a selection of different flours were mixed on the Farinograph. Doughs were mixed to a peak value of 600 BU in all cases and assessed for softness and stickiness immediately after mixing and after 40 mins rest at which point they were tested by the compression test.

RESULTS

Previous work with a limited set of doughs had also showed strong correlations with compression energy and both softness and stickiness as assessed by a baker[4]. These strong correlations can be seen with the much wider range of doughs used in the current work.

The correlations were shown to be significant in both cases, however, stronger correlations were found with the softness. A correlation of - 0.619 ($P < 0.001$) was seen between stickiness and the energy per unit area for compression. A correlation of - 0.802 ($P < 0.001$) was seen between bakers assessment of softness and the energy per unit area for compression (see Fig. 2).

A correlation of 0.790 ($P < 0.001$) was seen between the compression energy and the number of roller passes that could be completed (see Fig. 3).

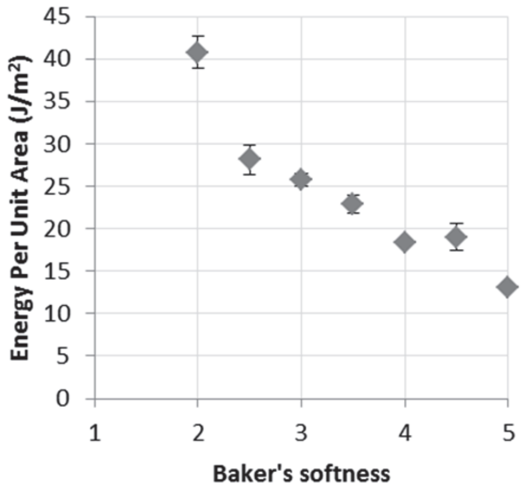

Figure 2. Graph showing the relationship between compression energy and bakers assessment of softness. Error bars show standard error. (n = 11, 10, 18, 12, 6, 2, 1). All triplicate compressions except for 1 duplicate in baker's softness = 2.

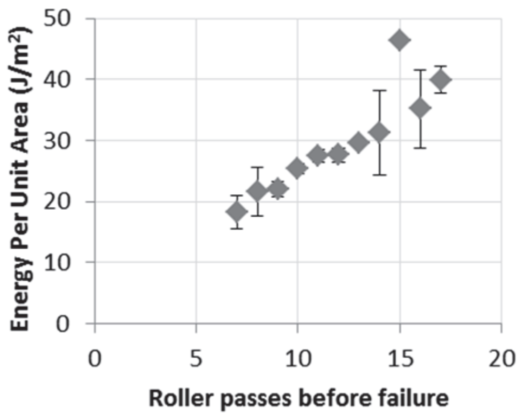

Figure 3. Graph showing the relationship between compression energy and quantitative dough handling assessment (max 17). Error bars show standard error. (n = 3, 3, 18, 11, 6, 4, 1, 3, 1, 2, 8) All triplicate compressions except for 1 duplicate in roller passes = 17.

Results for tests on different flours all mixed to the same consistency on the Farinograph showed quite different behaviour (see Table 1). The 600 BU consistency did not result in doughs with the same softness. Compression test results, however, did show differences at the point of testing. While in most cases the stickiness and softness immediately after mixing and after a rest period were similar, this was not the case for Flour 1. This highlights a potential issue caused by the time dependent changes in dough.

Table 1. Dough behaviour for four flours mixed to 600 BU consistency by Farinograph. Energy per unit area given as average ± standard error (n = 6, 6, 9, 8). All triplicate except flour 4; 4 in duplicate and 4 in triplicate.

Flour	**Observations after**		**Energy per unit area (J/m^2)**
	mixing	**resting**	
1	Not v soft or sticky	Very soft and sticky	14.1 ± 0.5
2	Very soft and sticky	Very soft and sticky	14.2 ± 0.3
3	Not v soft or sticky	Not v soft or sticky	24.3 ± 0.3
4	Not v soft or sticky	Not v soft or sticky	20.9 ± 0.6

DISCUSSION

The Brabender Farinograph is a commonly used test in the baking industry. The technique measures the torque on the mixer as the dough develops and is subsequently broken down. This torque is used as a measure of dough consistency and is used to determine how much water should be added in order to achieve a certain consistency. One of the issues with this technique is that it only relates to the dough behaviour at the point of mixing. Any time dependent behaviour post mixing, for example by enzymes, will affect the dough handling properties but will not be seen using this technique. The second issue is that the consistency measured by this technique does not always relate to the softness as assessed by a baker. This work demonstrated clearly different dough behaviour for different flours mixed to the same consistency, not only after a rest time, but also immediately after mixing (see Table 1). This highlights the need for an alternative technique for assessing dough behaviour, in particular dough softness.

Uniaxial compression has been used previously to study rheology of dough. Lubricated compression, in particular, has been used to look at biaxial extensional viscosity with the assumption of perfect slip at the interface[6,7,8]. Various assessments using lubricated compression have been performed including creep tests[9] and stress relaxation tests[10] and stress-strain modelling has been attempted[11,12]. These models generally assume a cylindrical sample with perfect slip at the interface.

In non-lubricated compression the situation is more complex as both biaxial extension and shear will be contributing factors to the material viscosity. Similar assessments to those performed with lubricated compression have also been performed with non-lubricated compression[13], although there are fewer examples of this, and stress-strain modelling has been attempted[11,13]. This generally assumes perfect stick at the interface allowing modelling of the barrelling of the initially cylindrical shape.

When a baker manually assesses the dough the baker will subject the dough to both shear and extension as the dough is handled. This interaction between shear and extensional properties appears to be important in the assessment of dough properties and relating instrumental results to bakers assessments. Consequently, non-lubricated compression has been used in this study. In dough compression it is expected that the actual situation will be stick-slip and consequently modelling is more challenging.

Consistent sample preparation is difficult to achieve with dough, particularly soft and sticky doughs. Previous work has used complex sample preparation techniques, generally involving lubrication of the surface, in order to minimise sample variation[8,11]. This technique using lubrication could not be used in this study as the interaction with the interface would be affected. For this reason approximately spherical dough pieces were used, rather than the easier to model cylindrical samples, as these were possible to produce more consistently without the use of lubrication.

The quantitative dough handling technique is a model system based on sheeting rollers. Industrially there would be a high throughput of dough between the rollers with a gradual build-up of dough on the rollers. This high throughput is difficult to replicate on a small scale so in this model system single dough pieces are passed multiple times between rollers with the aim of reproducing the dough build-up scenario on industrial rollers. Dough behaviour in this system has then been compared with the compression test results (see Fig. 3).

Correlations between the quantitative dough handling assessment and the compression test results suggest that, with further work, it may be possible to introduce a cut-off value below which it can be expected that dough will be difficult to process.

CONCLUSIONS

A strong and significant correlation was demonstrated between results from the compression of dough samples and stickiness. The results also showed a stronger and significant correlation with softness.

Significant correlations were also seen between compression energy and quantitative dough handling assessment. This suggests that, with further work, it may be possible to introduce a cut-off value in the compression test below which doughs could be expected to be difficult to process.

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