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Studies of Mixing Characteristics and Elasticity of Dough Using the Newport Scientific micro-doughLAB

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INTRODUCTION

The Newport Scientific micro-doughLAB is a prototype small-scale sigma-arm dough mixer, based on an earlier prototype z-arm instrument from the Value Added Wheat CRC (Haraszi et al., 2004), which tests 4 g of flour, and measures water absorption (WA) and dough mixing parameters. The novel torque measurement system and high speed data acquisition allows the instrument to dead-stop, while still measuring the residual torque as the dough relaxes. The relaxation of the dough may give an indication of its elasticity, allowing evaluation of both the viscous and elastic properties of dough throughout a single mixing test. The objectives of this study were to compare dough mixing parameters from the micro-doughLAB (4 g bowl) to those of the regular doughLAB (300 g bowl), and to assess the efficacy of obtaining elasticity data from the micro-doughLAB.

MATERIALS AND METHODS

Several flour samples with varying mixing characteristics (baker's, plain, and biscuit flours) were obtained from local sources.

The flour samples were first tested on the doughLAB, using the standard 30°C test (AACC Method 54-21), to determine the correct amount of water (optimum WA) to add to bring the peak consistency of doughs to 500 force units (FU). The optimum WA was then used to test those samples on the micro-doughLAB. Torque values from the micro-doughLAB were measured in milliNewtonmetres (mNm), with the peaks being centred around 124 mNm. Additionally, on the micro-doughLAB, the standard 30°C profile was modified to stop mixing at two points during the test: at peak consistency, and after 15 min. of mixing (overmixed dough). At each of these points, two small-scale deflection steps were introduced (creep test), according to the profiles shown in Table 1, and torque data obtained at high speed to monitor the viscoelastic properties of the optimum and overmixed dough.

TIME	TYPE	VALUE	TYPE	VALUE
Biscuit flour	Plain flour	Baker's flour		
00:00:00	00:00:00	00:00:00	Speed	63 rpm
00:00:00	00:00:00	00:00:00	Temperature	30°C
00:03:00	00:04:30	00:05:00	Speed	0 rpm
00:04:00	00:05:30	00:06:00	Speed	5 rpm
00:04:01	00:05:31	00:06:01	Speed	0 rpm
00:04:30	00:06:00	00:06:30	Speed	63 rpm
00:15:00	00:15:00	00:15:00	Speed	0 rpm
00:16:00	00:16:00	00:16:00	Speed	5 rpm
00:16:01	00:16:01	00:16:01	Speed	0 rpm
00:20:00	00:20:00	00:20:00	End	-

Table 1
Creep test profiles for biscuit, plain and baker's flour.

**The first dead-stop is timed to occur at peak torque, and is therefore different for different samples.*

Repeatability was evaluated by one-way analysis of variance (ANOVA) of data. WA, dough development time (DDT) and stability from the doughLAB and micro-doughLAB were compared by regression analysis (Minitab ver. 13).

RESULTS AND DISCUSSION

Comparison of doughLAB and micro-doughLAB results

Using the optimum WA as obtained on the doughLAB, the micro-doughLAB achieved a mean peak torque value of 124.8 mNm (Table 2), implying a conversion ratio of approximately 40:1 in torque between the 300 g and 4 g bowls. Results obtained from the doughLAB were more repeatable — with smaller root mean squares (RMS) and lower coefficients of variation (CV) — than those from the micro-doughLAB (Table 2). Nonetheless, the micro-doughLAB produced acceptable repeatability for assessing dough properties for routine use, for example in a breeding program.

Table 2
Summary of mixing properties of wheat flour doughs tested on the doughLAB and micro-doughLAB.

Parameter	doughLAB (300 g)			micro-doughLAB (4 g)		
	Mean	RMS	CV%	Mean	RMS	CV%
Peak ($FU_{(dL)}$ or $mNm_{(micro\text{-}dL)}$)	502.9	2.15	0.43	124.8	5.72	4.59
WA (%)	62.6	0.061	0.10	63.2	1.13	2.14
DDT (min.)	6.6	0.22	3.38	3.9	0.57	14.55
Stability (FU)	10.1	0.58	5.76	7.8	0.72	9.27

RMS = root mean square of the error term. CV (%) = coefficient of variation (relative repeatability standard deviation).

WA, DDT and breakdown data from the doughLAB and micro-doughLAB were compared by regression analysis. The observed coefficients of regression (R^2) indicated that the linear equations accounted for 99.3% (RMS of 1.13% WA units), 72.1% (RMS of 2.20 min.), and 92.4% (RMS of 1.56 min.), of total variability between the doughLAB and micro-doughLAB for WA, DDT, and stability, respectively (Table 3). Further work is required to validate these results on a larger set of samples.

Table 3
Regression equations for WA, DDT, and stability from doughLAB and micro-doughLAB tests on several flour samples.

Parameter	Regression	R^2	RMS
WA (%)	micro-dL WA = 0.8669 dL WA + 8.9149	0.993	1.13
DDT (min.)	micro-dL DDT = 0.6866 dL WA – 0.6129	0.721	2.20
Stability (min.)	micro-dL Stability = 0.9122 dL Stability – 1.4476	0.924	1.56

R^2 is the estimate of the variability accounted for by the regression, RMS is the root mean square of residuals of the fit.

Measurement of viscoelastic properties of dough on the micro-doughLAB

The exponential decay evident in the creep data provides a measure of the viscoelastic properties of each dough. At peak consistencies, the creep data of the plain (Figure 1C, 1D) and biscuit (Figure 1E, 1F) flours show more rapid decays (steeper decay curves) than that of the baker's flour (Figure 1A, 1B). This indicates that the baker's flour was stronger and more resilient to deflection than the plain and biscuit flours. For each different type of flour, the overmixed dough showed a steeper decay curve than the dough at peak consistency, indicating that the overmixed dough was more sloppy and less resilient to deflection.

Further work is required to quantify the viscoelastic properties, using a larger and more varied sample set, and setting a baseline to the torque decay measurements. Further studies comparing doughLAB, micro-doughLAB and Farinograph data are in progress.

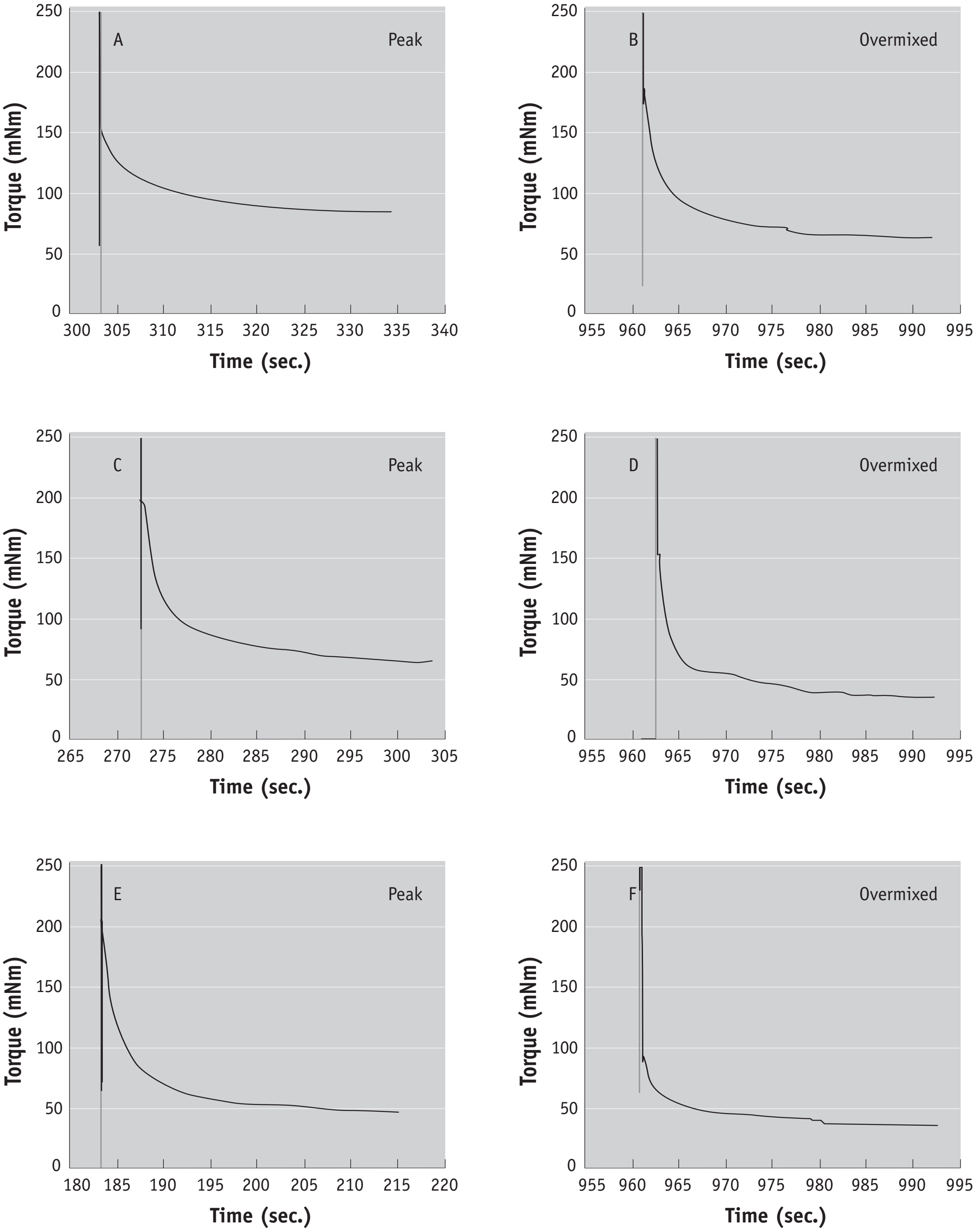

Figure 1
Small-scale deformation data for baker's (A, B), plain (C, D) and biscuit (E, F) flours at peak and overmixed consistencies.

CONCLUSIONS

The ability of the micro-doughLAB to provide mixing characteristics and viscoelastic properties of a dough from a single test, as well as its small-scale capabilities, makes it a potentially useful one-stop instrument for bakers, breeders, and researchers.

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The 'Hungarian Connection'

Every research discipline has its own tale to tell about its historical origins. In the late 1800s, breeders used the 'chewing test' — which relied on a good set of teeth — to measure milling quality. Cereal science as such, first started in Australia and has an interesting connection to Hungary.

In the 1890s, F.B. Guthrie — the very first cereal chemist — borrowed a promotional item from a booming milling company in Melbourne, which had imported more than 100 commercial wheat mills from Ganz and Company of Budapest, Hungary. As a promotion, good customers of the Melbourne firm received a Christmas gift, which was a working, timber-made mill model, milling 5–10 g of grain to flour. Guthrie took the model to his lab and used it to determine the milling yields of Farrer's wheat lines. And so, small-scale laboratory characterisation of grain/flour/dough was born.

Over a hundred years later, under the Quality Wheat CRC umbrella, CSIRO Plant Industry scientists Peter Gras and Ferenc Békés (both recipients of the 2000 Perten Award for their pioneering work on small-scale dough testing research and development) together with engineer Chris Rath, set about developing a micro-scale z-arm mixer, mimicking the Farinograph. The choice of collaborating partners for this work was obvious.

The original patent for the Hungarian version of the Farinograph, the Valorigraph — which was developed by Jenő Hankóczi in 1908 — came from Budapest. Furthermore, a generation of specialised experts of laboratory testing of cereals grew up in the Biochemistry and Food Technology Department of the Technical University of Budapest under the mentorship of the famous food rheologist and equipment developer, Radomir Lasztity. The final team was made up of scientists (Sándor Tömösközi, András Salgó, János Varga and Réka Haraszi) and József Nánási and Dezső Fodor, the engineers/founders of the small firm METEFEM (the successor of LaborMIM, a Budapest-based company which had several decades of experience in producing the Valorigraph).

The machinery and engineering design of the prototypes — even the bowl and the z-arms of the equipment today — came from Budapest, while the electronics and software of the original version were developed in Australia. Today's fully computerised micro-equipment, requiring not more than 4 g of flour to determine water absorption and mixing characteristics of dough, hopefully will prove as popular as its 'grandfather', the Farinograph.

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