Comparison of Alternative Recording Mechanisms (Mobile vs. Fixed-Bowl) for the 35- and 10-Gram Mixographs[1]

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ABSTRACT

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A 35-g and a 10-g mixograph were each modified to use alternative electronic recording mechanisms (mobile vs. fixed-bowl) to sense and record a dough's resistance to mixing. The first of these mechanisms used a linear taper potentiometer that followed the action of the moving bowl. The second employed a load cell connected to the mixograph mixing bowl arm, stabilizing it. Both the electronic recording methods were subjected to the same computer analysis software for each of the parameters measured. Comparisons were made between the mixograms produced from the two alternative electronic sensing mechanisms and conventional mixograms for each mixograph. Computer analysis of both the electronically recorded mixograms (potentiometer and load cell) was able to discriminate among flour samples as well as the conventional method, for each of the three parameters: time to peak, peak height, and tail width at 8 min. For all these three parameters, correlations between results for the different recording methods were as high as correlations between the 35- and 10-g mixographs and were highly significant in all cases.

The use of computerization in the collection and analysis of data improves the reproducibility and repeatability of research work and the standardization of work within and between laboratories. Manual analysis and data entry with the present mixograph design is also labor intensive and time-consuming. To overcome these inefficiencies, computer-assisted analysis of dough rheological properties has been proposed by a number of groups. Voisey et al (1966) developed a fixed-bowl recording mixer for 5- or 10-g flour samples that was similar in design to the 35-g mixograph. Dough resistance to mixing was measured by four strain gauges mounted on a beam (two on either side) and connected in a Wheatstone bridge. Rubenthaler and King (1986) fitted a 10-g mixograph with a linear variable differential transformer (LVDT) on the mixing arm. Navickis et al (1989, 1990) accomplished torque sensing on a 10-g moving bowl by attaching a linear, wire-wound potentiometer to the base of the mixing shaft arm. They later replaced the potentiometer with a Planax rotary position sensor that had no contacts, was linear, and had low friction. Stearns and Barta (1990) used an electronic recording system similar to that of Rubenthaler and King (1986); they fixed the mixing bowl arm of a 35-g mixograph by attaching a Schaevitz LVDT-type force transducer 17.3 cm from the center of the mixing arm.

As yet, no research group has reported the comparison of fixed vs. mobile bowl recording mechanisms on the same mixograph. The objective of this research was to compare alternative recording mechanisms (fixed vs. mobile) on both 35- and 10-g mixographs and to test the prototype data-analysis software program.

MATERIALS AND METHODS

Three U.S. commercial flour samples, two single-cultivar U.S. samples, and two single-cultivar New Zealand samples were selected for their widely varying dough rheological characteristics. The selection of the samples was based upon flour protein content, which ranged from 8.2 to 17.2%, and upon mixogram characteristics. An experimental split-plot design was used. This consisted of two mixographs, 35- and 10-g, and three recording methods, mobile-bowl (conventional and potentiometer) and fixed-bowl (load cell), on each mixograph at the main plot level; seven flour samples at the plot level; and three replicates at the subplot level.

A 35-g and a 10-g mixograph (National Manufacturing Division, TMCO, Lincoln, NE) were both modified to electronically record results by the addition of a 5,000-Ω linear taper potentiometer attached to the rotating bearing shaft of the mixer arm, beneath the base plate (Fig. 1). The position of the mixing arm (or pen) during the mixing of a dough was sensed by the potentiometer, giving an output voltage (analog signal) proportional to the mixing arm position. The analog signal from the potentiometer was amplified through a power supply and signal conditioner (custom designed and built by A. E. Walker, AEW Consulting, Lincoln, NE).

The same 35- and 10-g mixographs were also modified to electronically record results by the addition of a 10-lb (4.5-kg) or a 1.8-lb (816-g) load cell, models LCU-010 and LCL-816, respectively (Omega Engineering Inc, Stamford, CT). The load cell on the 35-g mixograph was attached to the mixer arm at the no. 1 spring slot position. The load cell on the 10-g mixograph was located on a slide able to move along a stainless steel bar. This allowed it to be positioned at any place between slots no. 1 and no. 12 (Fig. 2). Each load cell was connected to the mixer arm by a demountable stainless steel rod with adjustable collars. A dough's resistance to mixing was sensed by the load cell, giving an output voltage proportional to the applied torque. The analog signal from the load cell was amplified by a strain gauge power supply/amplifier/signal-conditioning module (model DMD465, Omega Engineering).

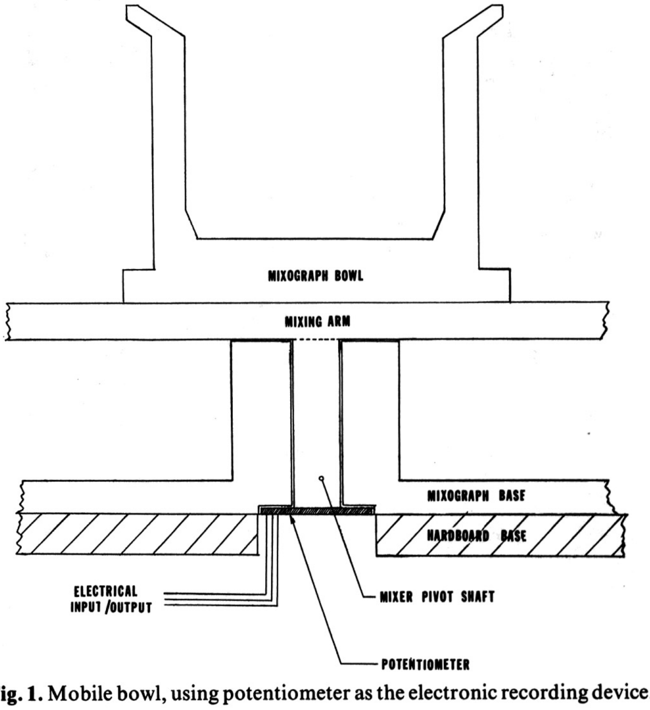

Fig. 1. Mobile bowl, using potentiometer as the electronic recording device.

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The analog signals from the potentiometer or load cell, after amplification and conditioning, were converted to digital values by an eight-channel analog-to-digital converter high-speed acquisition board (Metrabyte, model DAS-8, Taunton, MA) attached to an AT class computer (10 MHz, model 80286, with model 80287 numeric coprocessor, Legacy Technologies Ltd, Lincoln, NE).

A custom-written program, originally in GW BASIC (Microsoft Corporation, Redmond, WA) and subsequently compiled in Turbo BASIC (Borland International, Scotts Valley, CA) was used for collecting the data and evaluating the electronically recorded mixograms (potentiometer and load cell). Differences between the manual method and the electronic methods analyzed by computer may therefore arise from either of the automation stages (electronic recording device, software analysis program).

Torque measurements from the modified mixographs were taken at a frequency of 10 samples per second for 10 min. Conventional mixograms were obtained from the 35-g mixograph from which the original spring-spool-dampening system was removed and the 10-g mixograph from which the original weighted arm was removed. The dampening arms were replaced by aluminum plates (185 × 87.5 × 6.35 mm) and dampening weights (554.4 and 60.44 g for 35- and 10-g mixographs, respectively).

After the potentiometer had been attached to the moving shaft of the mixing bowl arm, and there were no other alterations from the conventional mixograph as described above, the chart paper was used to calibrate the potentiometer. With the computer on and connected to the potentiometer, the pen arm was swung across the width of the chart paper, sequentially being placed onto each of the lines. As the pen arm rested on each of the lines, the computer reading was recorded. Thereafter, the potentiometer was calibrated using these readings. Alternatively, weights may be used. Calibration of the mixograph (with potentiometer), using either placement of the pen arm on the chart paper lines or weights, showed hysteresis between the computer readings for increasing and decreasing torque directions on both the 35- and 10-g mixographs. The difference between digital computer readings for increasing and decreasing torque directions was ±2% of full scale.

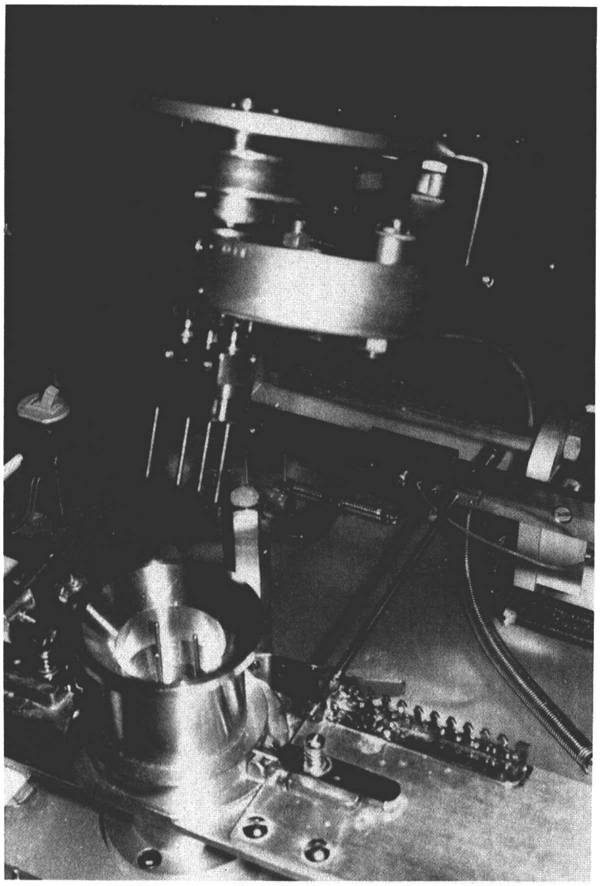

Fig. 2. Ten-gram mixograph, showing load cell connection to mixing arm.

When the mixing bowl arm is fixed, the load cell may be calibrated by the use of weights. A stand with a rod-mounted pulley was placed at right angles to the mixing arm, in front of the no. 12 setting. A line was attached at right angles to the no. 12 setting on the mixing bowl arm and over the pulley. The most important load cell calibrations are the no-load and maximum-load (full-scale) conditions, as these ensure that the correct recording span is set. In making these calibrations, 800- and 220-g loads were used for the 35- and 10-g mixographs, respectively.

The AACC mixograph method (1983, Method 54-40A) was used in conjunction with operating conditions and procedures as outlined in Finney and Shogren (1972). The only variations from the procedure were that the mixograph bowls and water were maintained at 25 ± 0.5°C in a water bath. Water was delivered to the flour sample via variable dispensettes (Brinkmann Instruments, Inc., Westbury, NY). For the 10-g mixograph, a 10-ml variable dispensette was used, which was set at 5 ml. For the 35-g mixograph, a 50-ml variable dispensette was used; this was set to 19 ml. An adjustable 5-ml Pipetman micropipette

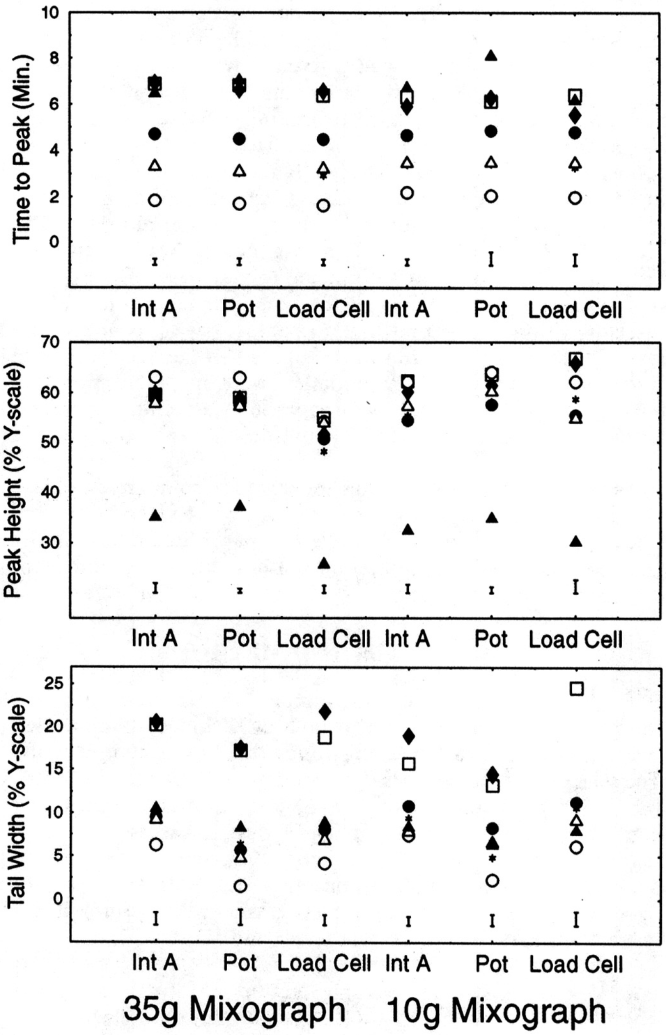

Fig. 3. Profile plots of time to peak, peak height, and tail width at 8 min. ■ = flour 1, 17.2% protein, U.S. Plainsman; ◆ = flour 2, 17% protein, U.S. Oslo; * = flour 3, 12.6% protein, N.Z. Otane; ○ = flour 4, 13.8% protein, N.Z. Kotare; ● = flour 5, 11.6% protein, U.S. all purpose; △ = flour 6, 11.3% protein, U.S. French bread; ▲ = flour 7, 8.2% protein, U.S. pastry flour; Int A = manual. All flours 14% mb. Error bars show least significant differences at 5% significance level from separate one-way analyses of variance of flour samples for each method.

(Rainin Instruments Co. Inc., Emeryville, CA) was then used to make up the difference between the settings of the dispensettes and the actual flour-water absorption required, which varied from sample to sample.

Time to peak (in minutes) of the center line, peak height of the center line (percent of width of chart paper), and tail width at 8 min (percent of width of chart paper) were recorded manually for the 35- and 10-g mixographs. Also, electronic mixogram recordings from the load cells and potentiometers on the 35- and 10-g mixographs were analyzed automatically by the computer software.

Statistical analysis of results for time to peak of the center line, peak height of the center line, and 8-min tail width was performed using the SAS statistical package, version 6.04 (SAS Institute 1985).

RESULTS AND DISCUSSION

Each of the three recording methods—mobile-bowl (conventional and potentiometer) and fixed-bowl (load cell)—provided equally good differentiation among the flour samples. Profile plots and least significant differences at the 5% significance level from separate one-way analyses of variance (ANOVAs) are shown in Figure 3.

Results from ANOVA did show some interactions that were significant at the 0.05 level for time to peak (minutes), peak height (percentage of total *y*-scale), and tail width at 8 min (percentage of total *y*-scale) between analysis methods and flour samples. Profile plots revealed that the interactions were not orderly; therefore, a test of main effects was inappropriate.

Examination of the profile plot and results from one-way ANOVA for time to peak and mixograms showed that the results recorded by potentiometer for flour 7 were significantly higher than the results using other methods of analysis. This produced a change in order and magnitude of the mean time to peak for the methods of analysis, contributing to the significant interactions.

For all flour samples and analysis methods, the difference in replicates for time to peak ranged from 0.00 to 1.34 min at the 95% confidence level. The greatest difference between replicates was in the results for flour 7, a pastry flour for which the peak was very poorly defined because of the very flat mixogram curve. Adjustment of the regression analysis along with the use of default values or comments for zero within the software program would improve the ability to handle mixogram curves of minimal gradient.

TABLE I

Correlation Coefficients Between 10- and 35-g Mixogram Times[a] to Peak Recorded Manually and Electronically

Method of Analysis	10-g Mixograph		35-g Mixograph		
	Potentiometer	Load Cell	Manual	Potentiometer	Load Cell
10-g Mixograph					
Manual	0.978	0.990	0.979	0.995	0.991
Potentiometer		0.946	0.929	0.965	0.961
Load cell			0.977	0.983	0.980
35-g Mixograph					
Manual				0.992	0.994
Load cell					0.997

[a] *r* value based on means.

TABLE II

Correlation Coefficients Between 10- and 35-g Mixogram Peak Heights[a] Recorded Manually and Electronically

Method of Analysis	10-g Mixograph		35-g Mixograph		
	Potentiometer	Load Cell	Manual	Potentiometer	Load Cell
10-g Mixograph					
Manual	0.977	0.975	0.977	0.979	0.988
Potentiometer		0.964	0.987	0.988	0.994
Load cell			0.942	0.940	0.951
35-g Mixograph					
Manual				0.998	0.986
Load cell					0.983

[a] *r* value based on means.

Pearson correlation coefficients for time to peak between 10- and 35-g mixograms, those recorded and analyzed manually and those recorded electronically and computer analyzed, varied from 0.929 to 0.997 (Table I).

Examination of the profile plot and results from one-way ANOVA for peak height showed an interaction that was not orderly between results recorded and analyzed manually and those recorded electronically and computer analyzed.

TABLE III

Correlation Coefficients Between 10- and 35-g Mixogram Tail Widths[a] at 8 min Recorded Manually and Electronically

Method of Analysis	10-g Mixograph		35-g Mixograph		
	Potentiometer	Load Cell	Manual	Potentiometer	Load Cell
10-g Mixograph					
Manual	0.942	0.992	0.950	0.993	0.973
Potentiometer		0.942	0.957	0.945	0.962
Load cell			0.965	0.943	0.981
35-g Mixograph					
Manual				0.993	0.992
Load cell					0.985

[a] *r* value based on means.

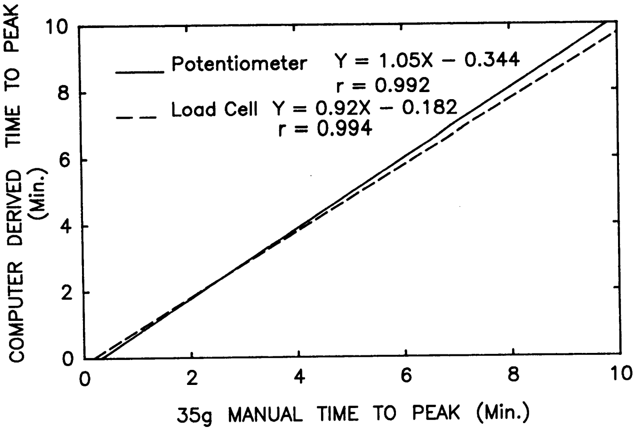

Fig. 4. Computer-derived time to peak from electronically recorded mixograms vs. manually analyzed time to peak from conventional mixograms (35-g bowl).

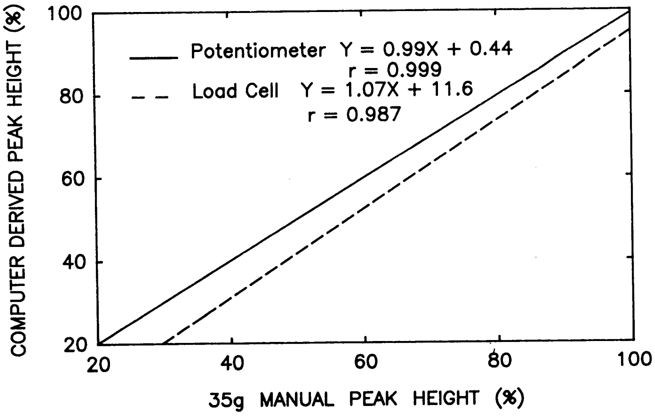

Fig. 5. Computer-derived peak height from electronically recorded mixograms vs. manually analyzed peak height from conventional mixograms (35-g bowl).

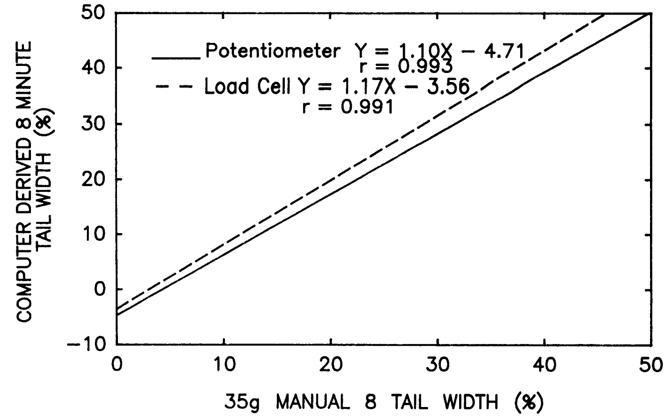

Fig. 6. Computer-derived 8-min tail width from electronically recorded mixograms vs. manually analyzed 8-min tail width from mixograms (35-g bowl).

Pearson correlation coefficients for peak height between 10- and 35-g mixograms, recorded and analyzed manually and recorded electronically and computer analyzed, varied from 0.940 to 0.998 (Table II). The correlations among the three methods on the 10-g mixograph and among the three methods on the 35-g mixograph were as high as the three correlations between the 10- and 35-g mixographs for the three methods. This highlights the consistency of electronically recorded and computer-analyzed results when compared with manual methods of interpretation.

Examination of the profile plot and results from one-way ANOVA for tail width at 8 min revealed an interaction that was not orderly between results recorded using a load cell and other methods of recording.

Pearson correlation coefficients for tail width at 8 min between 10- and 35-g mixograms, recorded and analyzed manually and recorded electronically and computer analyzed, varied from 0.933 to 0.993 (Table III).

Electronically recorded mixograms were found to have wider tail widths at 8 min than manually recorded mixograms. Of the

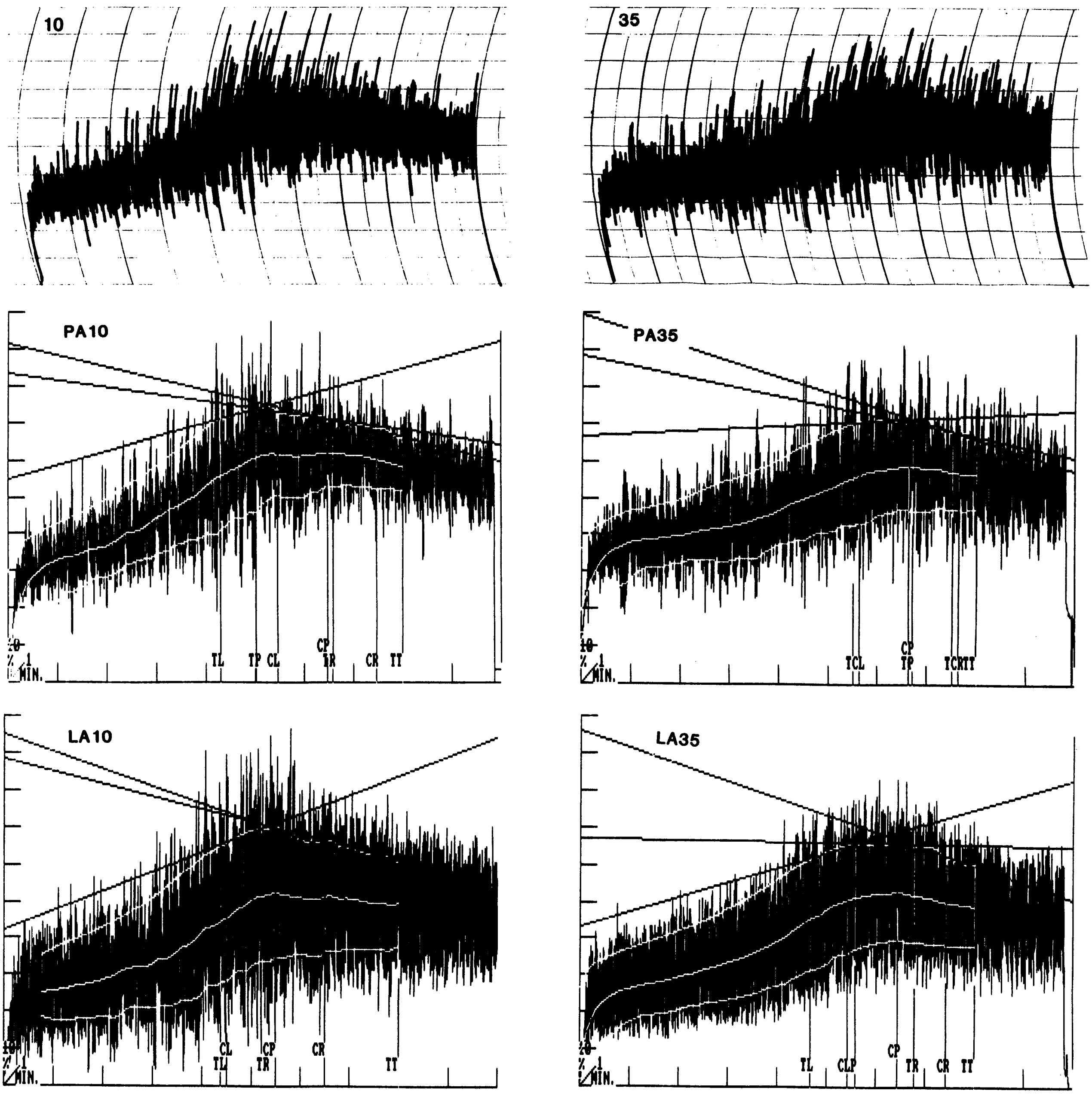

Fig. 7. Comparison of 10- and 35-g mixograms using conventional recording method and electronic (potentiometer and load cell) recording methods (flour 1). 10 = 10-g conventional mixograph, PA10 = 10-g mixograph with potentiometer attached to the base of the bowl base shaft, LA10 = 10-g mixograph with load cell attached at right angles to the mixing shaft, 35 = 35-g conventional mixograph, PA35 = 35-g mixogram with potentiometer attached to the base of the bowl base shaft, LA35 = 35-g mixograph with load cell attached at right angles to the mixing shaft.

two electronic recording mechanisms (potentiometer and load cell), the load cell had the wider tail width, especially on 10-g mixograms. This was possibly due to more noise where the load cell was smaller and more subject to distortion and hysteresis.

Figures 4–6 show the linear relationships between 35-g mixograms manually recorded and 35-g mixograms electronically recorded and computer analyzed for time to peak, peak height, and tail width at 8 min, respectively.

Figure 7 compares mixograms from each of the recording mechanisms on the 10- and 35-g mixographs. The mixograms recorded electronically by load cell can be seen to be wider. This could be adjusted within the computer software program and the hardware calibration procedures if necessary.

CONCLUSIONS

The results for both computer-analyzed methods of recording, mobile bowl (potentiometer) and fixed bowl (load cell), displayed very good correlation with the manually recorded (conventional) results for each of the three parameters (time to peak of the center line, peak height of the center line, and 8-min tail width).

It is possible that the type of load cell used on the 10-g mixograph might have a reduced working life due to the excess torque imposed on it during placement and removal of the mixing bowl from the mixing arm. This could be overcome by a latch on the mixing arm that would secure it during bowl change operations, or by a rapid disconnect to the load cell arm.

As the electronic methods were shown to be comparable, the choice between using a potentiometer or a load cell is a matter of personal preference. Primarily this would be dependent upon such factors as cost, ease of installation and maintenance, and the need or desire to record results using either the conventional moving bowl action or the fixed bowl. The potentiometer records the basic rotary motion of the mixer arm as a measure of the dough's resistance to mixing, as does the conventional method of mixogram recording. The moving bowl action provides varying orientation between the mixing bowl pins and the mixing planetary pins; this variation in pin orientation does not occur with the fixed bowl. Fixed-bowl values for time to peak and peak height do vary with bowl position (Walker, *unpublished data*).

Electronic recording of results from the mixograph are of great value to the cereal chemist studying dough quality. Although more research is required to identify those parameters that may best be obtained from electronically collected data, the reproducibility and repeatability increases the value of the mixograph as a research and quality control tool.

Both torque-sensing devices were relatively easy to install. In terms of maintenance, the load cell was the easier to reach, but it required daily calibration. The load cell on the 10-g mixograph was more prone to drift than the larger load cell on the 35-g mixograph. The potentiometer used in these experiments was a low-cost unit that required regular cleaning of the contact surfaces with acetone to avoid excess signal noise. As the potentiometer was located in the base below the mixing arm shaft, cleaning it was awkward.

The cost of updating to an electronic torque-recording system can probably be justified by the improved reproducibility of results within a laboratory (when compared with conventional methods for recording and analyzing mixograph data), where operator bias may be a factor. Conversion using a load cell could cost less than U.S. $1,000. This includes the following equipment: 80287 numeric coprocessor, data acquisition card, terminal board, cable, load cell, power supply, and load cell mounting bracket. Conversion of the mixograph to use a potentiometer would be slightly less. One would also need access to an MS-DOS computer (512K memory, AT class recommended) plus data acquisition and analysis software, not included in the above cost estimates. The improved accuracy and precision would also be applicable to interlaboratory studies. The calibration of these modified mixographs by weights also facilitates interlaboratory standardization. Although the results obtained for the load cell and potentiometer were comparable, the potentiometer used was observed to have a hysteresis effect that did not apply to the load cell.

ACKNOWLEDGMENT

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 54-40A, approved April 1961, revised October 1988. The Association: St. Paul, MN.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flours. Baker's Dig. 46:32-35, 38-42, 77.

NAVICKIS, L. L., BUTTERFIELD, R. O., and NELSON, T. C. 1989. A modified electronic torsion sensor for a 10-gram mixograph with computerized data acquisition and analysis. Cereal Chem. 66:350.

NAVICKIS, L. L., RUBENTHALER, G. S., NELSON, T. C., and BUTTERFIELD, R. O. 1990. Evaluating mixogram parameters by electronic torque sensing. Cereal Foods World 35:493.

RUBENTHALER, G. L., and KING, G. E. 1986. Computer characterization of mixograms and their relationship to baking performance. Pages 131-167 in: Fundamentals of Dough Rheology. H. Faridi and J. M. Faubion, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

SAS INSTITUTE. 1985. Guide for Personal Computers, version 6.04. The Institute: Cary, NC.

STEARNS, M. M., and BARTA, S. 1990. Mixograph standardization/digital data acquisition. Cereal Foods World 35:485.

VOISEY, P. W., MILLER, H., and KLOEK, M. 1966. An electronic recording dough mixer. I. The apparatus. Cereal Chem. 43:408.

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