AN ELECTRONIC RECORDING DOUGH MIXER

IV. Applications in Farinography[1]

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ABSTRACT

The advantages of electronic recording methods have been shown in relation to recording pin-type mixers. The application of these methods to the farinograph are described here to show that the same advantages can be applied to farinography. Modification of a farinograph to record electronically is described. The new design is a more flexible research instrument than are previous designs. A wider range of sensitivities and greater accuracy are possible. Calibration is done by gravity weights; this simplifies standardization of the recording system. The damper is eliminated from the recording mechanism, and the width of the development curve is a precise measurement related to the physical properties of the dough. Typical development curves recorded with the new apparatus are shown, and a new technique for accurate absorption measurements is demonstrated.

The farinograph is widely used for estimating the quality of dough (1). Calibration of the machine is difficult, because a damper is used in the measuring mechanism (2,3). The time for the recording arm to move between two graduations is measured and adjusted to between 0.6 and 0.8 sec. (4). The measuring system records a dynamic torque signal, but the damper is used to reduce oscillations of the recording system to 80 units wide (1). The width and top of the curve are therefore not related to the strength of the dough, because the excessive damping specified reduces the width of the curve to an arbitrarily selected value. The farinograph is therefore used mainly for comparative tests, and in its present form it is not suitable for rheological studies of bread dough. The top of the development curve is used to report arrival time, development time, stability, tolerance, and valorimeter values (1). Friction in the mixing bowl is eliminated from the records by zeroing the recorder with the mixer running empty. However, friction in the recording system itself introduces the same problems as in the mixograph (2).

The oil specified for the damper (S.A.E. 10W) (1) has a viscosity range of 6,000 to 12,000 Saybolt universal sec. (S.u.s.) and changes approximately 10 S.u.s. per degree F. (5). This allows considerable latitude in the damper performance. A better choice of oil is possibly

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a viscosity standard (Brookfield Engineering Lab., Stoughton, Mass.). The damper is calibrated under one condition; this does not test its performance under the wide range of dynamic conditions present during the mixing process. The force exerted on the dynamometer arm of the farinograph, by the damper, is proportional to the velocity of the dynamometer arm. An accurate calibration procedure to overcome this is complex (e.g., measure width of curve with known input torque fluctuations). The width of the curve is not accurately recorded, because the recording system cannot follow the torsional fluctuations; the upper and lower peaks are clipped off (2). Thus, use of the upper part of the curve to interpret any of the data is meaningless. The mathematical analysis of such a system has been widely published (6).

The standard farinograph has three sensitivity settings; its use is limited to sample sizes too large for many genetic studies, and the sensitivity is too low to test weak flours. However, 10-g. bowls are used (7) in a specially modified machine. Curves are recorded over half the chart width, because mid-scale is used as the consistency line. This limits the resolution of measurement. The chart is graduated, and data are reported in Brabender Units. An accurate calibration in fundamental units cannot be given because of the points already stated. The graduations correspond to the displacement of the recording arm with the damper disconnected. Thus, data obtained with the farinograph are comparative, not fundamental. The adjustment of the damper is critical, and comparison of flour on different machines cannot be made accurately. This is evident from data already published (1) and is due mainly to differences between mixing bowls and blades and partly to problems associated with calibrating the recording mechanism.

The electronic farinograph overcomes some of these problems. A modification is described to eliminate the damper and convert the farinograph to electronic recording. Thus, the advantages described for the electronic recording mixer (2) are achieved with the farinograph. The width of the development curve, which is related to dough strength, is recorded accurately and can be used to obtain data in the same manner as by the electronic recording mixer (2). The new design offers the following advantages: simplified and rugged mechanism; accuracy is higher; range of operation is more flexible; and accurate calibration methods can be used. The sensitivity of the recorder covers a wide range and can be changed during a development curve, allowing high sensitivity during titration procedures; thus the accuracy of absorption determination is increased. Any point on the scale can be selected as the consistency line.

Description of Apparatus and Methods

A farinograph is modified by removing the levers, scale, and damper of the recording system (Fig. 1, a). A strain-gaged beam *C* (Fig. 1,b) is fixed rigidly to the base of the machine at one end and connected

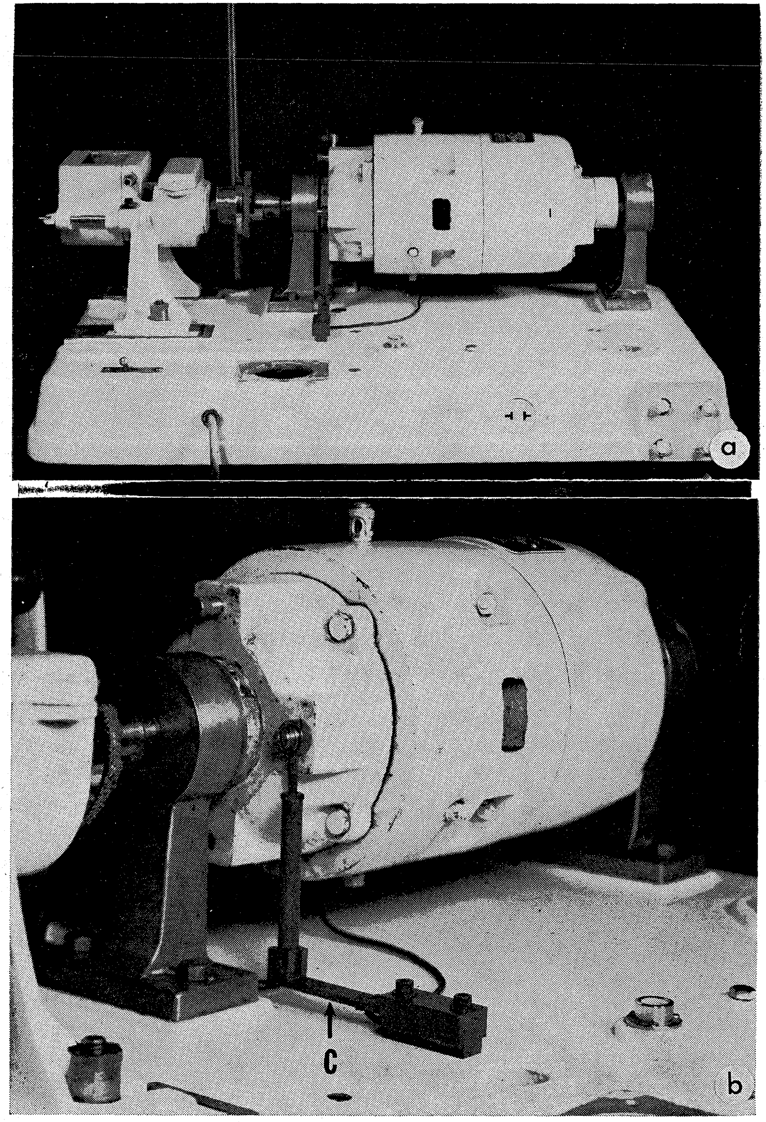

Fig. 1. The modified farinograph. a, the simplified mechanism; **b, close-up of** motor, showing *C*, the strain-gaged beam.

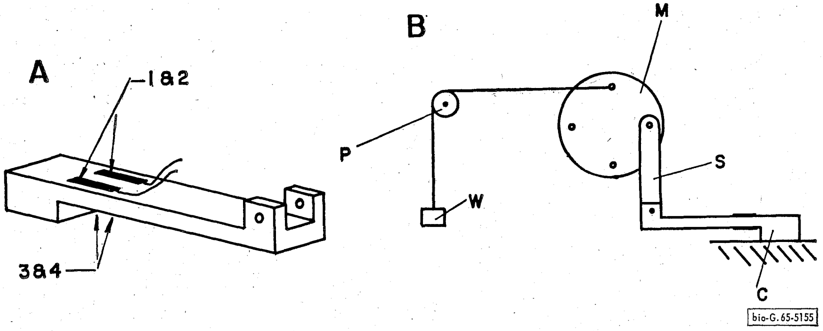

Fig. 2. A, the strain-gaged beam made of aluminum; 1 to 4, strain gages. B, method of calibration: *M*, motor mounted in bearings; *P*, pulley; *C*, strain-gaged beam; *S*, pin-jointed link; *W*, gravity weight.

to the motor at the other by a pin-jointed link *S* (Fig. 2, B). When the farinograph is in operation, the torque reaction of the motor produces strain in the beam. The strain gages form a Wheatstone Bridge which is connected to equipment similar to that already described for the recording mixer (2,8). The electronic farinograph is operated and calibrated by the procedures adopted for the mixer (2,8).

The new apparatus is demonstrated by recording development curves for 50-g. samples (14% m.b.) of a commercial bread flour using the electronic recording apparatus described for the recording mixer (2,3,8). The total moisture is added in 25 sec. (with the motor running).

The amplifier (Type 300 CF, with Type 80 plug-in, Daytronic Corp., Dayton, Ohio), used to amplify the output of the strain gages for recording, has a zero suppression control. The zero torque position on the recorder chart can be moved up or down scale. Both the zero suppression and sensitivity dials of the amplifier can be calibrated in units of torque. Thus, the mean torque due to friction in the bowl, gears, and motor can be eliminated from the records. The farinograph is operated with the sample bowl empty and the zero suppression control adjusted until the recorder reads zero.

The zero suppression control can be used during titration of added moisture to allow an increase in the sensitivity of the recording system. The recorder is calibrated so that 25% (or any selected percentage) of maximum torque gives full-scale recorder deflection. Seventy-five per cent of maximum torque is applied and the suppression control adjusted to give zero on the chart. The recorder then registers only the upper 25% of the development curve. The controls for sensitivity and zero suppression can be adjusted during a development curve because they are calibrated, and the chart reading can be converted to torque at all settings. For example, the complete development curve can be plotted at high sensitivity by rezeroing the recorder whenever the curve reaches full scale. The zero suppression technique is demonstrated by adding excess moisture, 3 drops at a time, to the dough during mixing to show the greater sensitivity.

Results

Typical calibration curves of torque *vs.* chart reading were linear within ± 0.5% compared with the nonlinear calibration of a farinograph (Fig. 3). The torque during mixing fluctuated at 3 c.p.s. (top section, Fig. 4) with minor variations at 27 c.p.s. superimposed, caused by vibration of the gearing in the drive motor and mixing head. The minor variations were eliminated electronically. With the sample bowl empty the torque fluctuated from 0 to 300 cmg. because of intermittent friction in the gearing of the drive motor and bowl (lower section, Fig. 4). This must be subtracted from the width of the curve to obtain the true width during mixing.

Typical curves recorded electronically are shown (Figs. 5 and 6) to

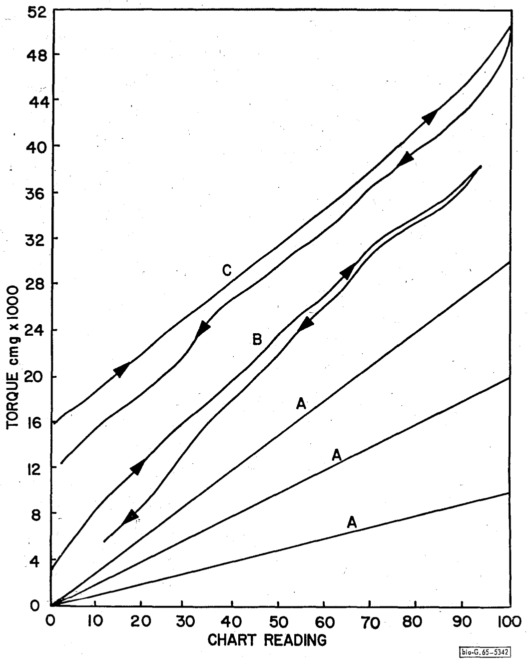

Fig. 3. Typical calibration curves. Curve A: electronic machine; curves B and C: Brabender Farinograph, (B) with damper connected, and (C) with damper disconnected (low range).

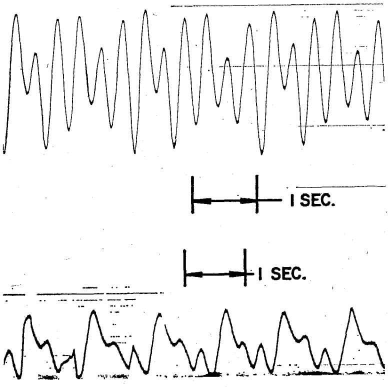

Fig. 4. Record of torsion fluctuations. Upper: after 9.0 min. of mixing; lower: with sample bowl empty, showing effect of friction in the gears.

demonstrate the versatility of the electronic farinograph. A full statistical analysis of the method will be published later. The illustrations show that the frequency response of the recorder has the same effect on the curve width as in the case of the recording mixer (3). Results using the zero suppression technique (Fig. 5, curves at lower right) show the sensitivity of the electronic recording system.

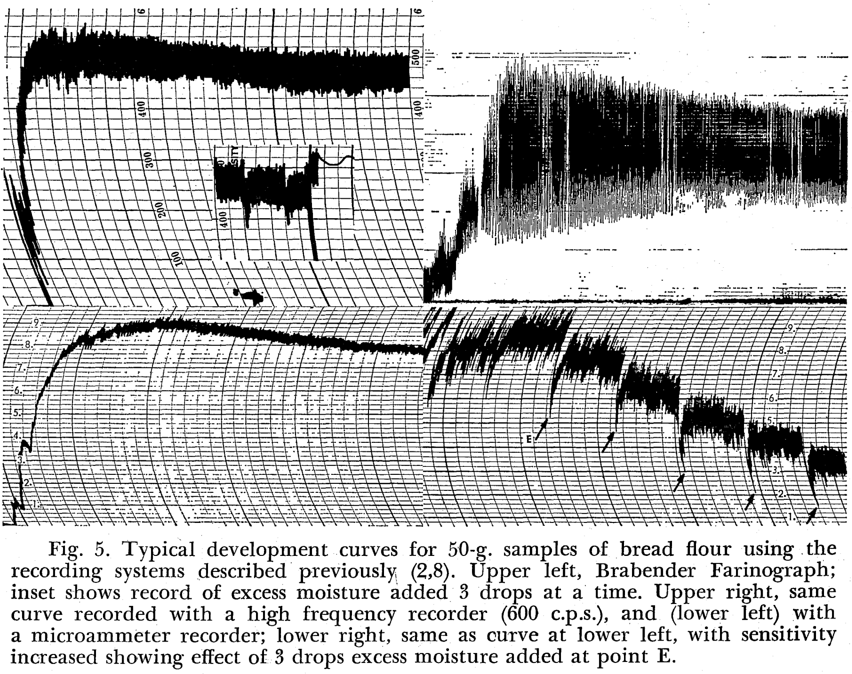

Fig. 5. Typical development curves for 50-g. samples of bread flour using the recording systems described previously (2,8). Upper left, Brabender Farinograph; inset shows record of excess moisture added 3 drops at a time. Upper right, same curve recorded with a high frequency recorder (600 c.p.s.), and (lower left) with a microammeter recorder; lower right, same as curve at lower left, with sensitivity increased showing effect of 3 drops excess moisture added at point E.

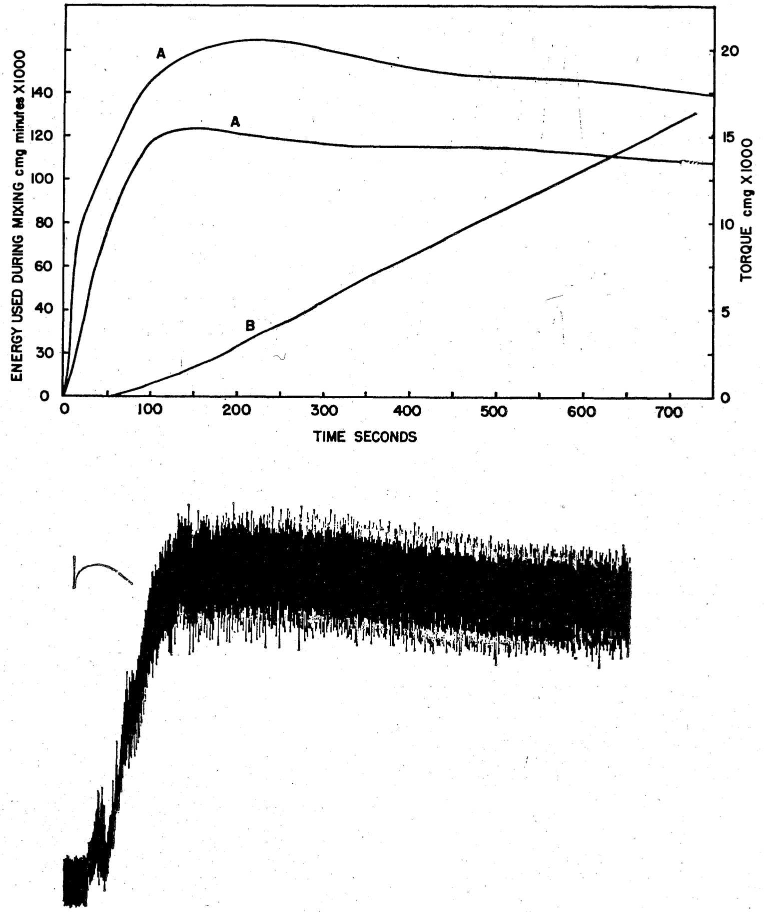

Fig. 6. Continuation of Fig. 5. Above: curves A, maximum and minimum torque during mixing; curve B, integral of torque during mixing. Below: record using T-Y recorder.

Discussion

The results shown demonstrate the versatility and increased accuracy of the new design. The design shown is simple and inexpensive. It can be manufactured for about the same cost as a farinograph because many of the existing mechanical parts are eliminated. The method is not ideal, because friction in the motor, its support bearings, and the mixing-bowl gears are recorded and a correction to the width of the curve is required. This can be overcome, but in that case the design would be more complicated.

The sensitivity of any mechanical displacement mechanism measuring torsion is limited. At high sensitivity, friction and inertia form a large part of the forces within the system. The electronic machine overcomes this, because friction in the recorder is eliminated and high sensitivities are easily arranged by amplification. The inertia of the measuring system is reduced, and high-frequency torsional fluctuations are measured precisely by using a suitable recorder (2,3).

Conclusions

Modification of the farinograph to record electronically removes some of the difficulties in calibrating the apparatus. Interlaboratory standardization of the recording apparatus can be achieved accurately with the use of independent methods to standardize the torque recording system. It is more accurate and versatile than existing machines. The electronic method is suitable for extending the application of the farinograph method to study fundamental properties of dough. However, considerable research will be required to make this possible.

Summary

In this and the three preceding papers a simple modification of two instruments (the mixograph and the farinograph), used widely for testing the quality of bread dough, was described. The modification increases the range of application of both instruments for both research and quality control. Considerable work is needed to investigate the potential applications of the new method. Problems associated with the existing instruments and the way in which electronic apparatus may be used in overcoming them were discussed. The new method and its application can be summarized as follows:

1. The mechanical recording mechanism is replaced by an electronic system which can be calibrated accurately with the use of gravity weights. Data can then be reported in fundamental units.

2. The torque exerted on the dough during mixing can be recorded by any instrument that will accept a millivolt signal. This includes analog, digital, and integrating recorders, and the optimum collector of data, a computer.

3. The physical data on which flour quality is judged can be arranged to suit a particular purpose by using different methods of recording, ranging from a complex analog curve for analysis to a single number (the integral) related to energy absorption.

4. The two established instruments must be investigated further to

determine the possibility of their use to measure the fundamental rheological properties of dough.

5. The electronic apparatus makes the testing of small samples easier because a robust, almost frictionless transducer with high sensitivity can be used. The modification may therefore find application in other instruments used by the cereal chemist, such as the amylograph.

6. The energy absorption of dough can be determined more precisely with the electronic apparatus, since it is measured directly, not indirectly, as in the case of a wattmeter coupled to the mixing motor. This is of considerable value in the study of breadmaking methods using mechanical dough development such as the Chorleywood process. The method can be used in production-type mixers. Its major application will be in research instruments where small samples are used and a higher degree of precision is required.

A major area requiring investigation to increase the usefulness of the mixograph and farinograph is the problem of interchangeable bowls. This is the major difficuty in accomplishing independent interlaboratory standardization. A simpler mixer that is easier to produce but will mix doughs efficiently is required.

Acknowledgment

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