The Ottawa Electronic Recording Dough Mixer. VI. Differences between Mixing Bowls[1]

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ABSTRACT

An electronic recording dough mixer for 5-g. flour samples is described. An evaluation of this mixer, testing commercial hard and soft flours, indicated that four mixing bowls, constructed to precisely the same dimensions, gave different results. The differences were statistically significant, but it was concluded that for practical purposes the bowls were interchangeable. The problem of making interchangeable mixing bowls and mixer pins increases as mixer size is reduced. The results indicate a need for standardization in the fabrication of recording micromixers.

The authors previously described a modification to convert a recording dough mixer by replacing the mechanical recording apparatus with a strain-gage torque transducer and an electronic recording system (1). Conversion of a mixograph (2), a farinograph (3) and a Hobart mixer (4), and the development of a mixograph-type mixer for 10-g. flour samples (1) have also been described. The electronic recording mixer was demonstrated by testing mixtures of commercial flours (2), and different recording techniques were described (5,6,7).

A major problem encountered with these mixers and previously by other workers using different mixers was the noninterchangeability of mixing bowls (2). The purpose of the work reported here was to develop a mixer for 5-g. flour samples with interchangeable bowls. This is a critical performance factor in any research mixer. To achieve interlaboratory standardization, bowls must be interchangeable. If more than one mixing bowl is available, testing can be done more quickly; while one bowl is in use the others can be made ready for subsequent operation.

MATERIALS AND METHODS

The mixer used for this experiment was similar to apparatus previously described (1), with the following modifications which increase its usefulness as a research mixer: 1) An improved bowl pivot and transducer mounting were used (Fig. 1,C). 2) The size of the mixing bowl was reduced to 3.15 cm. in diam. and 1.90 cm. deep to accommodate 1- to 5-g. samples of flour (Fig. 2,D). 3) A detachable disc was placed over the mixer pins to prevent dough from moving up the mixer pin shafts (Fig. 2,E). 4) Mixing speeds ranging from 40 to 980 r.p.m. were obtained by using a variable-speed motor (model NSH-12 with type W-14 control, Minarik Electric Co., Los Angeles, Calif.). 5) An adjustable electronic thermostat maintained the mixer cabinet temperature within ± 0.25°C.

The mixer was installed in a self-contained cabinet, together with the equipment required to control the mixing speed, mixing time, and cabinet temperature (Fig. 1,A). The torque transducer was connected to an amplifier (model 300D-80, Daytronic Corp., Dayton, Ohio) whose output was connected to a potentiometer-type strip-chart recorder which had a 3.0-sec. full-scale response time

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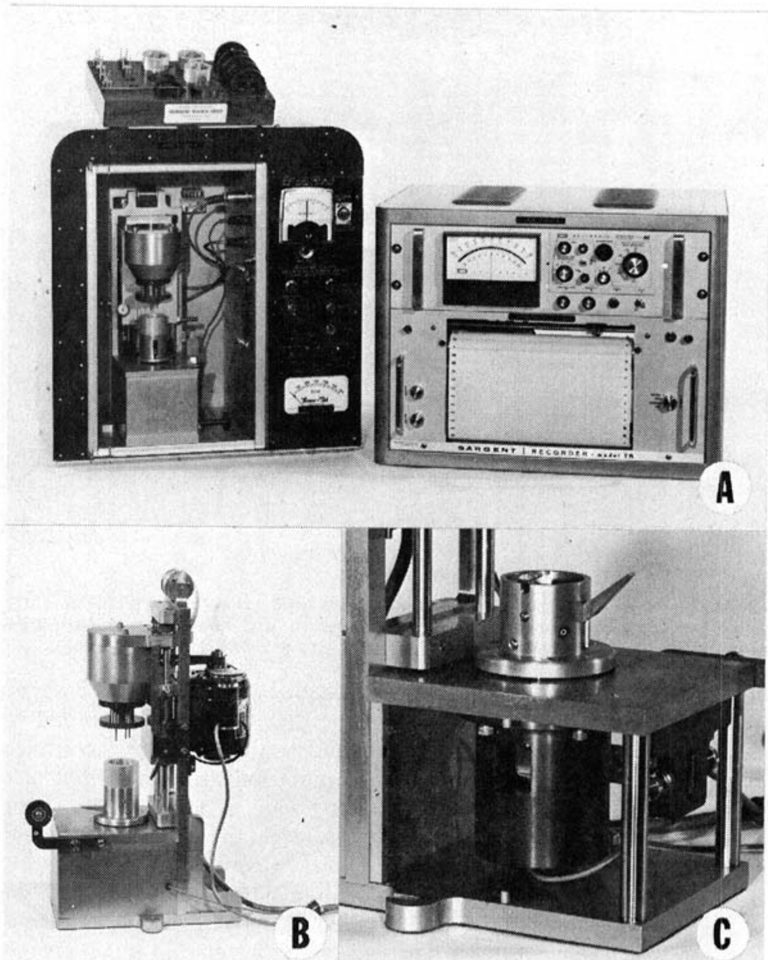

Fig. 1. A, Ottawa electronic recording mixer and recording apparatus; B, the mixing showing fixture for applying torque to the transducer by a weight; C, details of a torque transducer and pivot.

was less than ± 0.5% in 24 hr. after a 4-hr. warm-up period. The natural frequency of the torque transducer was 100 Hz (cycles per sec.) compared to the 50 Hz of the previous design (1).

(model TR, E.H. Sargent & Co., Chicago, Ill.). The amplifier and recorder were assembled in a separate cabinet (Fig. 1,A). The recorder chart and mixing motor were controlled simultaneously by the mixing timer.

Four mixing bowls, four pairs of mixer pins, and four mixer pin discs were fabricated for the mixer. The smallest possible dimensional tolerances were used to ensure that these parts were mechanically interchangeable. For identification, the bowls and mixing discs were numbered 1 to 4 and the pairs of detachable mixing pins were lettered K, L, M, and N respectively.

The torque transducer calibration was checked at full-scale sensitivities ranging

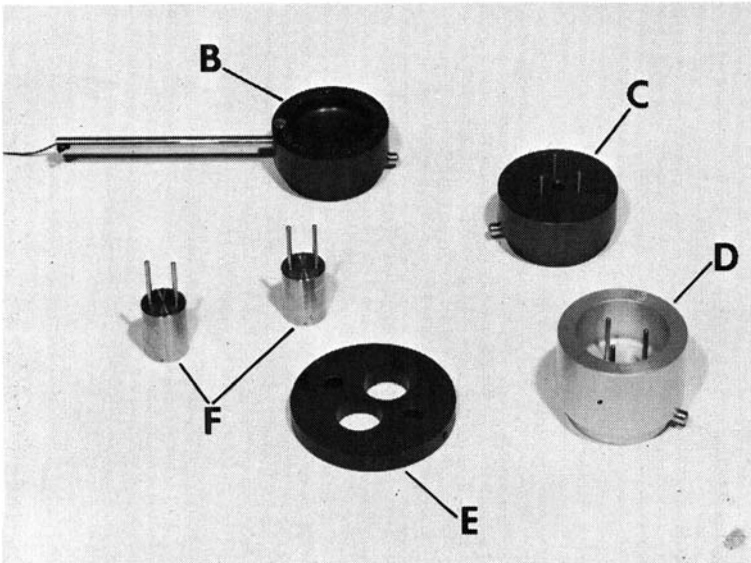

Fig. 2. Mixing bowl and accessories: B, fixture for calibrating torque transducer; C, fixture for checking geometry of mixing plans; D, mixing bowl; E, disc to prevent dough from working up mixer pin shafts; F, mixer pins.

from 500 to 10,000 cm. g.; weights and a calibration fixture (Fig. 2,B) were used to simulate mixing torque (1,2,7). This indicated that torque was recorded within ± 0.5% at all points on the scale. Drift of zero and sensitivity of the recording system

Commercial bread and cookie flours were purchased from local mills and their moisture content (8) and water absorption (9) were determined. Ten samples of each flour were tested with each of the 16 possible combinations of bowls and mixer pins. All samples were corrected to 14% m.b. (5-g. flour sample).

The flour samples were weighed on an analytical balance to within ± 2 mg. The added water was dispensed by a 5-ml. "pipettor" said to deliver within ± 0.5% (model 13-689, Fisher Scientific). The flour, added water, and mixer cabinet were maintained at 25°C.

Each sample was mixed at 100 r.p.m. for 7.5 min. A line was drawn on the resulting development curves at the estimated mean torque during mixing (2) and the following measurements were noted: (a) energy absorbed during mixing, in meter-kg. (i.e., area under mean curve); (b) maximum torque during mixing, in cm.g.; (c) torque after 7.5 min. of mixing, in cm.g.; (d) time to reach the maximum torque in min.

RESULTS AND OBSERVATIONS

Preliminary tests indicated that the bowls were not interchangeable. The dimensions and general shape of the development curves were different for each bowl. A major source of these differences was that the bowl pins were not parallel. A jig was constructed so that this error could be measured and corrected. The pins, made of type 303 stainless steel, bent slightly after several samples had been processed. The pins were therefore replaced with pins made of type 431 stainless steel, which had three times the strength of type 303.

TABLE I. MEANS AND COEFFICIENTS OF VARIATION FOR MEASUREMENTS TAKEN FROM DEVELOPMENT CURVES OBTAINED WITH 16 COMBINATIONS OF PINS AND BOWLS

			Energy Absorbed during Mixing				Maximum Torque during Mixing				Torque after 7.5 min. of Mixing				Time to Maximum Torque			
			Hard Flour		Soft Flour		Hard Flour		Soft Flour		Hard Flour		Soft Flour		Hard Flour		Soft Flour	
Bowl	Pins	Disc	Mean[a] m.-kg.	C.V. %	Mean[a] m.-kg.	C.V. %	Mean[a] cm.g.	C.V. %	Mean[a] cm.g.	C.V. %	Mean[a] cm.g.	C.V. %	Mean[a] cm.g.	C.V. %	Mean[a] min.	C.V. %	Mean[a] min.	C.V. %
1	K	1	36.98	2.12	22.34	2.56	1,075.76	2.62	625.62	1.68	711.07	2.62	431.83	3.50	2.27	3.30	1.83	4.20
2	L	2	37.14	3.28	22.41	0.13	1,080.34	3.71	622.57	2.62	755.32	2.64	427.25	2.34	2.14	4.63	1.75	4.15
3	M	3	36.25	2.06	21.92	4.18	1,052.87	1.96	619.52	3.87	686.66	2.71	416.57	3.34	2.26	2.42	1.77	3.60
4	N	4	36.95	2.40	22.23	0.22	1,065.08	3.01	628.67	2.96	694.28	1.74	416.57	2.79	2.22	6.30	1.78	6.10
1	L	2	36.66	2.80	22.30	2.68	1,057.45	3.04	630.20	2.64	698.86	3.22	416.57	3.74	2.29	3.53	1.74	4.38
2	M	3	36.55	2.13	22.17	2.65	1,052.87	2.45	627.14	2.54	692.76	2.27	407.42	3.07	2.29	5.01	1.81	4.56
3	N	4	36.22	2.38	22.15	2.67	1,033.03	2.11	614.94	3.36	695.81	2.53	419.62	2.63	2.32	4.61	1.81	5.41
4	K	1	37.14	0.15	22.49	2.63	1,063.55	1.93	624.09	2.50	712.60	1.92	427.25	5.56	2.26	3.34	1.72	4.98
1	M	3	36.53	2.36	22.79	1.42	1,062.03	3.49	650.03	3.07	695.81	2.83	419.62	2.63	2.30	5.03	1.66	5.00
2	N	4	36.89	2.61	22.86	1.61	1,060.50	2.10	651.56	2.61	700.39	2.10	422.67	1.94	2.27	3.90	1.65	5.08
3	K	1	37.01	2.52	22.88	3.13	1,066.60	2.54	646.98	2.36	706.49	1.76	427.25	4.98	2.33	4.49	1.66	6.49
4	L	2	36.83	2.20	23.02	2.30	1,063.55	1.98	653.09	3.20	692.76	2.86	436.41	2.59	2.29	14.36	1.73	7.15
1	N	4	36.25	2.72	23.13	2.82	1,052.87	2.68	659.19	2.74	689.71	2.70	431.83	3.04	2.28	3.71	1.69	7.71
2	K	1	36.77	1.98	23.39	2.62	1,058.97	2.08	663.77	3.76	700.39	1.70	440.99	3.27	2.30	3.49	1.63	7.00
3	L	2	36.24	2.34	23.16	2.86	1,042.19	2.24	660.71	2.57	694.28	2.51	434.88	3.69	2.39	2.67	1.63	6.18
4	M	3	35.98	2.67	23.11	1.95	1,036.09	1.91	657.66	1.58	674.45	3.00	430.30	2.46	2.35	3.85	1.66	7.22
Mean[a]			36.64	....	22.65	....	1,057.45	....	639.35	....	697.34	....	425.73	....	2.28	....	1.72	....
C.V. %			1.01	....	1.97	....	1.21	....	2.74	....	1.43	....	2.01	....	2.47	....	4.09	....

[a]Ten samples.

[b]One hundred sixty samples.

TABLE II. ANALYSIS OF VARIANCE

Source	D.F.	Energy Absorbed during Mixing		Maximum Torque during Mixing		Torque after 7.5 min. of Mixing		Time to Maximum Torque	
		M.S.	F	M.S.	F	M.S.	F	M.S.	F
Hard flour[a]									
Subgroup	15	0.6687	1.80	0.0703	2.26	0.0340	2.45	0.0317	3.53
Bowl (B)	3	0.5704	1.53	0.0750	2.41	0.0094	0.68	0.0433	4.83
Pins (P)	3	1.4466	3.89	0.0870	2.80	0.1176	8.46	0.0059	0.61
B X P	9	0.4421	1.19	0.0631	2.03	0.0143	1.03	0.0364	4.06
Error	144	0.3718		0.0311		0.0139		0.0090	
Soft flour[a]									
Subgroup	15	0.9706	5.62	0.1206	9.06	0.0314	3.88	0.0450	4.74
Bowl (B)	3	0.1540	0.89	0.0134	1.01	0.0027	0.34	0.0035	0.37
Pins (P)	3	0.3143	1.82	0.0038	0.28	0.0520	6.42	0.0048	0.50
B X P	9	1.4616	8.47	0.1953	14.68	0.0341	4.21	0.0722	7.61
Error	144	0.1726		0.0133		0.0081		0.0095	

[a]Ten samples tested by 16 cominations of bowls and pins.

The height of the mixer pins above the bowl was found to be critical. This dimension determined the clearance between the mixer pins and the bottom of the bowl. A stop and latch were arranged to maintain this clearance at 0.78 mm.

It was observed that the first one or two samples processed each day had different development curves. Since the apparatus was left on continuously and procedures kept constant, it was assumed that this was due to the need for wetting the surface of the bowl. This error was eliminated by discarding the first samples each day.

It was observed that there was variation within each bowl, caused by the amount of water added to each sample. Initially, a pipet was used for dispensing water. The accuracy of this technique was compared with the accuracy of an "automatic pipettor" by dispensing 20 samples of water with each pipet. The amount of water dispensed each time was determined by weighing the samples. The automatic pipettor was more accurate, reducing the range of errors from −3.95 to 3.13% to −1.8 to 1.1%, and it was therefore adopted for the experiment.

Preliminary tests indicated that samples ranging from 1 to 5 g. of flour could be tested. A sample size of 5 g. was selected, since ample flour was available. A full-scale torque range of 1,500 cm.g. was found suitable for testing hard and soft flour samples of this size.

The mean value and coefficient of variation for the four measurements taken from the development curves were calculated for each combination of bowl and mixer pins and for each flour (Table I). The variation in 160 samples of each flour was small, ranging from 1.01% for the energy absorbed by hard flour to 4.09% for the time to maximum torque in soft flour. The variation tended to be lower for the hard flour. For each combination of bowl and pins, the coefficient of variation was different for each measurement and for each combination. Except for time to maximum torque, however, the range of these coefficients was generally small.

The data for the two flours were subjected to analysis of variance, which indicated that for each of the four measurements the differences were significant at either the 1 or 5% level (Table II). The bowl and pins, or a combination of bowls and pins, were sources of this variation. The reason for this was that although the

TABLE III. COMPARISON OF COEFFICIENTS OF VARIATION OBTAINED WITH ONE AND FOUR MIXING BOWLS

Flour No.[a]	Energy Absorbed during Mixing, Sample size (g.):			Maximum Torque during Mixing, Sample size (g.):			Torque after 7.5 min. of Mixing, Sample size (g.):			Time to Maximum Torque, Sample size (g.):		
	5	10	30	5	10	30	5	10	30	5	10	30
	%	%	%	%	%	%	%	%	%	%	%	%
H1	6.0	4.0	1.6	4.8	1.2	1.3	3.0	2.2	3.3	5.2	9.7	7.0
H2	...	...	3.9	...	...	4.4	...	...	3.3	...	...	4.8
H3	...	...	4.7	...	...	6.2	...	...	4.3	...	...	4.1
H4	...	...	2.4	...	...	...	...	...	...	...	...	...
H5	1.0	...	...	1.2	...	...	1.4	...	...	2.5	...	...
H6	3.3	...	...	3.7	...	...	3.2	...	...	14.4	...	...
S1	6.3	5.1	1.6	6.2	0.6	0.2	8.5	2.1	2.0	8.1	6.4	8.3
S2	...	...	8.5	...	...	5.9	...	...	1.0	...	...	11.5
S3	...	...	5.1	...	...	6.7	...	...	2.9	...	...	8.1
S4	...	...	3.3	...	...	...	...	...	...	...	...	...
S5	2.0	...	...	2.7	...	...	2.0	...	...	4.1	...	...
S6	3.1	...	...	3.9	...	...	5.6	...	...	7.7	...	...

[a]H, hard; S, soft. Flour 1, data from ref. 2; 10 samples; single bowl and comparable electronic recording system. Flours 2, 3 and 4, data from ref. 7; 10 samples, single bowl: 2 with mixograph, 3 with comparable electronic recording system, 4 with electronic integrator. Flour 5, 160 samples, 16 combinations of bowls and pins. Flour 6, 10 samples, maximum variation in 16 combinations of bowls and pins.

variation within each combination tended to be small, the mean value for each combination was different from the mean. Thus, on the over-all average, the differences tended to cancel each other. For practical purposes the differences between the means were considered small enough to be ignored.

The variation obtained with the 16 combinations of pins and bowls was compared with previous experiments (2,7) where a single bowl was used. This indicated that the maximum variation obtained in this experiment with 10 samples and 16 combinations was of the same order as that previously obtained with a single bowl (Table III). For energy and torque measurements, with 5-g. samples, the variation was reduced, possibly because of improved experimental techniques. In most cases the variation within one or 16 bowl-pin combinations was less than the variation (2) with a standard mixograph and single bowl.

The time to reach maximum torque in this experiment and previous work (2,6) had a higher variation than all other measurements, indicating the unreliability of this measurement (Table III).

DISCUSSION

It appears that it is not possible to fabricate mixing bowls and mixer pins for a micromixer that are precisely interchangeable, even when these components are made with extreme mechanical precision. As the size of the mixer is reduced, the clearance between the stationary and moving pins is reduced, thus making the geometry of the mixer pins more critical. The effect of any error is thus magnified. This may also be of importance in larger mixer, particularly of the pin type.

The dough rarely touches the sides of the bowl after dough formation; therefore, the spacing and arrangement of the pins determines the mixing torque. This indicates an important requirement for establishing standards for pin-type recording mixers. All dimensions of the components, and the tolerances within which they can be fabricated, must be clearly specified with extreme precision, especially where interlaboratory standardization is necessary.

The small variation achieved with 16 combinations of bowls and pins compares favorably with that obtained with a single bowl. The fact that flour is a viable material that has variable properties must be taken into consideration. If part of the variation in the data is attributed to this source, it can be assumed that the mixer described gives reproducible results.

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