NOTE

A Five-Gram Mixograph to Determine and Predict Functional Properties of Wheat Flours

K. F. FINNEY[1]

ABSTRACT

Described is a 5-g mixograph to determine and predict functional properties of wheat flours. Mixograms from the 5- and 10-g instruments were entirely comparable and highly replicable. A mixogram time-to-peak difference of 0.276 min between any two single values is required for significance at $P = 0.05$. The 5-g instrument has several structural improvements not on previous 10-g models. Mixograms of flours representing a wide range in mixing time to peak and in protein content were comparable for the 5- and 10-g instruments.

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Finney and Shogren (1972) downsized the 35-g mixograph to require only 10 g of flour to determine or predict important physical dough and breadmaking properties of early generation plant breeders' wheats. In 1988, the 10-g instrument was further downsized to require only 5 g of flour, thereby enabling wheat breeders to discard many undesirable lines earlier in the time-consuming breeding process. In the present study, a 5-g mixograph is described and compared to the 10-g instrument relative to construction, mixograms, and mixogram replicability.

[1]Consultant, U.S. Grain Marketing Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, 1515 College Avenue, Manhattan, KS 66502.

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MATERIALS AND METHODS

Developmental research was required to establish the weight and desirable dimensions of the damping arm for the 5-g mixograph. Spring extensibility research involved the diameter of spring wire, diameter of spring, number of coils per centimeter, and length of spring. Depth of bowl and length of pins in the bowl and planetaries had to be established. It was desirable to increase the work and sample storage space in the 5-g mixograph cabinet by developing a relatively short damping arm and relocating its stops. When room temperature is not controlled, small flour samples, ingredients, solutions, and water can be kept in a temperature-controlled mixograph cabinet.

TABLE I
Flour Protein Content, Flour Absorption, and Mixogram Time to Peak of Four Cultivars Replicated Three Times on the 5- and 10-g Mixographs

Cultivar	Flour		Mixogram Time to Peak (min)					
	Protein (%)	Absorption (%)	Rep 1		Rep 2		Rep 3	
			10 g	5 g	10 g	5 g	10 g	5 g
A	13.4	65.6	6 1/8	6	6	5 7/8	6	6
B	14.4	66.4	1 5/8	1 1/2	1 3/4	1 3/4	1 5/8	1 5/8
C	18.6	71.6	4 1/4	4 1/4	4 1/4	4 3/8	4 1/8	4 1/2
D	8.7	59.5	6 1/2	6 3/8	6 1/2	6 1/2	6 1/2	6 5/8

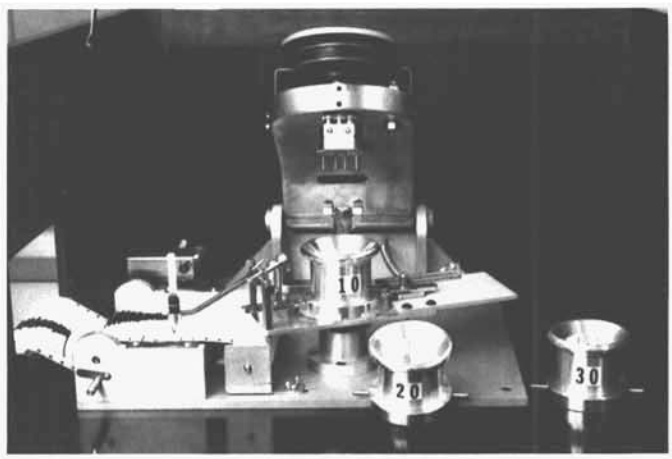

Fig. 1. Mixograph for recording mixing properties of 5-g samples of wheat flours. Bowl no. 10 is in operating position (on the bowl platform) directly below the raised mixing head and its two planetaries. Each planetary has two pins that revolve in a predetermined pattern about three stationary pins in the bowl. Attached to the right side of the bowl platform is the rectangular damping arm. The spring is attached at the back of the mixograph, and its slot hook is attached on the damping arm. To the left of the bowl platform is the balanced pen arm. Screw-in pen with black drawing ink exerts only about 6 g of pressure on the recording paper.

A new 10-g mixograph was used for standardizing the 5-g instrument and for comparing mixograms made on the two instruments. Replications and comparisons of 5- and 10-g mixograms were made on different days to increase the significance of the data.

Flours

To compare mixograms of the 5- and 10-g instruments and to demonstrate their replicability, four experimentally milled straight-grade flours of pure hard red winter wheat cultivars harvested at Manhattan, KS, were selected to represent a wide range in functional (breadmaking) properties. Cultivar A, Qv/Tm//Mq/Oro from the 1980 crop, has a long dough-mixing requirement, other strong physical dough properties, and a very good loaf volume potential. Cultivar B, KS501097 also from the 1980 crop, has a short to very short mixing requirement, other weak physical dough properties, and poor loaf volume potential. Cultivar C, Shawnee from the 1981 crop, has a high protein content, a medium-long mixing requirement, other good physical dough properties, and a very good loaf volume potential. Cultivar D, Newton from the 1983 crop, has a low protein content, a long mixing requirement because of low protein content, other good physical dough properties, and a very good loaf volume potential when considering protein content. Flour protein contents and absorptions are given in Table I.

Mixing Requirement and Protein Content Series

Cultivars A and B were used to make 100:0, 75:25, 50:50, 25:75, and 0:100 flour blends and thereby create a mixing time series that varied from about 6 to 1 5/8 min. Cultivars C and D were used to make 100:0, 75:25, 50:50, 25:75, and 0:100 flour blends, which represented a protein content series that varied from 18.6 to 8.7%. Mixograms were made on the 5- and 10-g instruments.

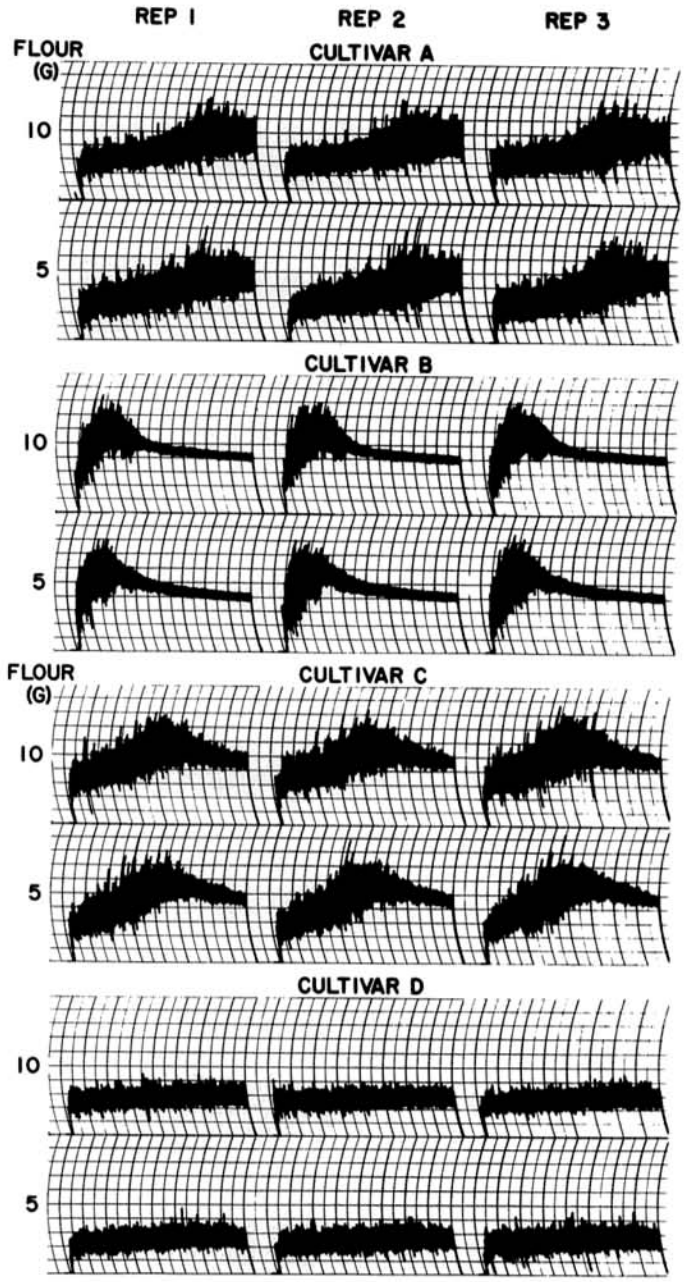

Fig. 2. Mixograms of cultivars A, B, C, and D, each replicated three times on the 5- and 10-g mixographs (Table I).

RESULTS AND DISCUSSION

Five-Gram Mixograph

Figure 1 shows the 5-g mixograph. It has several structural improvements not on previous 10-g models. Several castings have been replaced with parts precisely machined from dimensional

duralumin. The bowl platform is adjustable so that the head can be precisely centered over the bowl pins. A simple, rectangular, relatively small damping arm permits an increase in storage and work space. The damping arm and bowl platform stops are attached to the post back of the bowl platform, thereby further increasing work space. The front of the bowl platform is constructed so that flour and dust particles can be brushed out.

Bowl and planetary pins. The space between bottom of planetary pins and bottom of 10-g bowl is 0.889 mm, so that dough from 10 g of flour is stretched on 34.925 mm − 0.889 mm or 34.036 mm of 10-g pin. Then 34.036 mm ÷ 2 = 17.018 mm pin length on which dough for 5 g of flour will be stretched, and 17.018 mm + 0.889 mm = 17.907 mm pin length for the 5-g instrument. Thus, 34.925 mm − 17.907 mm = 17.018 mm decrease in depth of the 10-g bowl in construction of the 5-g bowl.

Damping. The simple rectangular damping arm is 8.89 × 13.18

TABLE II
Analysis of Variance of Mixing Times to Peaks of Triplicated 5- and 10-g Mixograms of Four Bread Wheat Cultivars that Varied Widely in Functional Properties

Source of Variation	df	Sum of Squares	Mean Squares	*F* Value
Size (S)	1	0.000651	0.000651	0.08 ($P >>> 0.20$)
Cultivar (C)	3	86.350912	28.783637	3,401 ($P <<< 0.001$)
S × C	3	0.054043	0.018014	2.13 ($0.20 > P > 0.10$)
Samples (S,C)	16	0.135410	0.008463	···
Total	23	86.541016	···	···

TABLE III
Comparison of Flour Blends Made to Give Ranges in Mixing Time to Peak and Flour Protein Content

Flour in Blend (%)	Blend Protein (%)	Blend Absorption (%)	Mixogram Time to Peak (min) 10 g	Mixogram Time to Peak (min) 5 g
Cultivars A:B[a]				
100:0	13.4	65.6	6	6 1/8
75:25	13.7	65.8	4 3/4	4 3/4
50:50	13.9	66.0	3 5/8	3 7/8
25:75	14.2	66.2	2 3/4	2 5/8
0:100	14.4	66.4	1 5/8	1 5/8
Cultivars C:D[b]				
100:0	18.6	71.6	4 1/4	4 1/4
75:25	16.1	68.6	4 3/4	4 7/8
50:50	13.7	65.6	5 1/2	5 3/8
25:75	11.2	62.5	6	6
0:100	8.7	59.5	6 1/2	6 1/2

[a]Cultivars A and B were blended to give a range in mixing time to peak.
[b]Cultivars C and D were blended to give a range in flour protein content.

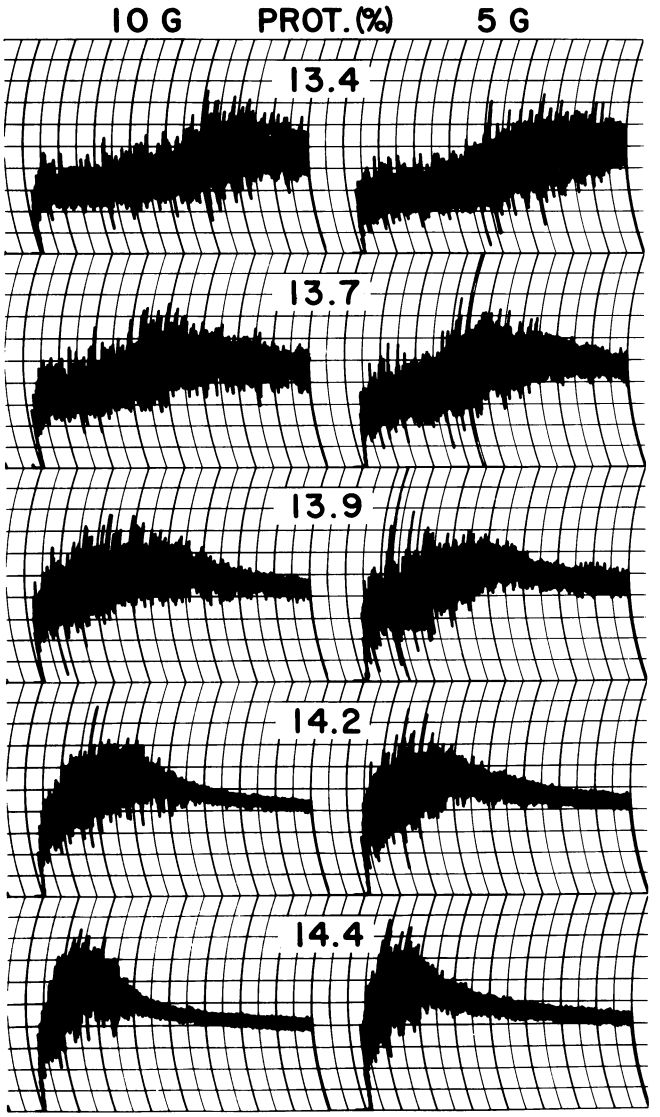

Fig. 3. Mixograms (5- vs. 10-g) of cultivars A and B and their 75:25, 50:50, and 25:75 flour blends made to give a range in mixing time to peak (Table III, top).

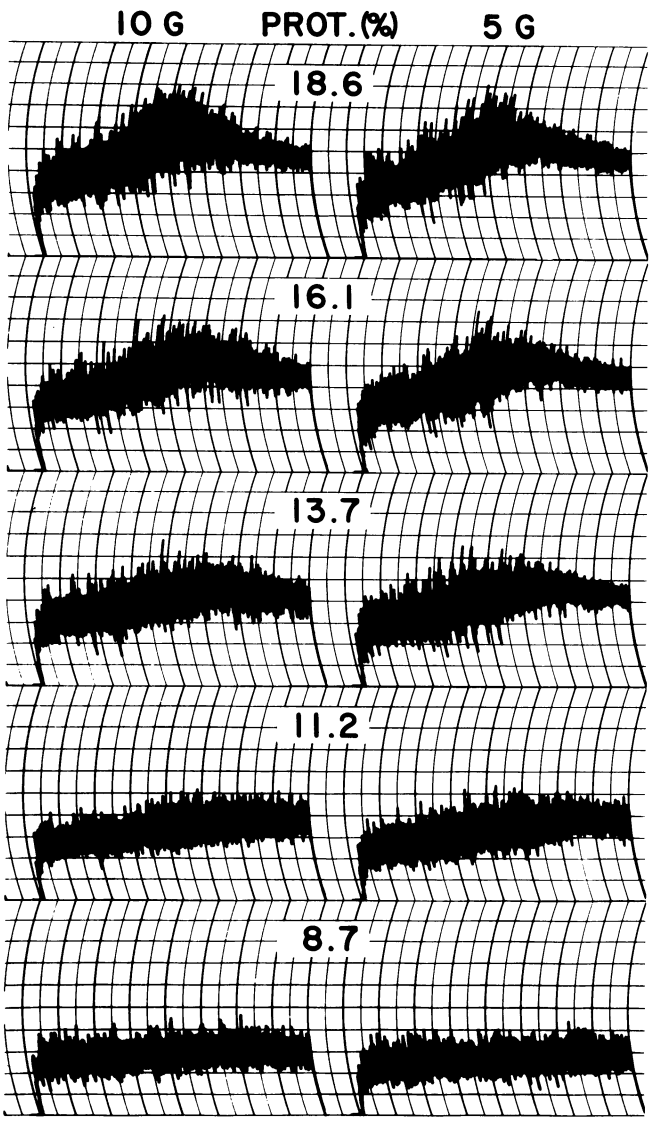

Fig. 4. Mixograms (5- vs. 10-g) of cultivars C and D and their 75:25, 50:50, and 25:75 flour blends made to give a range in flour protein content (Table III, bottom).

TABLE IV
Categorization of Mixing Requirement and Tolerance (physical dough properties) and Related Properties Predictable from Mixogram Mixing Time to Peak

Mixogram			Properties Predictable from Mixogram Mixing Time			
Mixing Time (min)	Mixing Tolerance	Physical Dough Properties	Dough Handling	Water Requirement	Bromate Requirement	Loaf Volume
Long (5 1/4–7 1/4)	≧ Good	Very strong to bucky	···	≧ Good	Small	≧ Good
Medium-long (3 3/4–4 3/4)	≧ Good	Strong	Good	≧ Good	Medium small	≧ Good
Medium (2 3/4–3 1/4)	Fair to good	Mellow to medium strong	Fair to good	Good	Medium	≧ Good
Short (1 3/4–2 1/4)	Poor to fair	Weak to mellow	Poor to fair	Poor to good	Medium large	Poor to good
Very short (1–1 1/2)	Very poor to poor	Very weak to weak	Very poor to poor	Very poor to fair	Large	Very poor to fair

cm, constructed from 4.76 mm duralumin, and weighs 135 g.

Spring. The spring is constructed from 0.711 mm wire and has an extensibility of 7.0 ± 0.1 cm/100 g when applying several weights of 50 to 200 g. The threaded tail of spring is attached at the back of the mixograph and its slot hook is attached on the damping arm. Other details are the same as for the 10-g instrument (Finney and Shogren 1972).

Other dimensions. Outside dimensions of the bowl, planetaries, and other related details are essentially the same as those for the 10-g instrument described in detail by Finney and Shogren (1972).

Replicability of Mixograms

Overall mixograms and times to peaks (points of minimum mobility) for the 5- and 10-g instruments (Fig. 2, Table I) are nearly identical for each of the four cultivars A, B, C, and D within and between replicates.

Mixograms of cultivar D are low on the mixogram paper, rise slowly, and have abnormally long times to peaks (av. 6.5 min, Table I), because of the low protein content of only 8.7% (Table I). Mixing time to peak corrected to 12% protein (Finney and Shogren 1972) would be 4 min, an expected value for cultivar D (Newton) at 12% protein. The formula for the calculation is $6.5 - [(12.0 - 8.7)\ 0.12]\ 6.5 = 4$, where 12.0 (% protein) and 0.12 are constants.

Statistical

Analysis of variance (Table II) was applied to mixogram mixing times to peaks of cultivars in Figure 2 and tabulated in Table I. Variation is largely attributable to the wheat cultivars, because they represented a wide range in mixing time, and peak times of 5- and 10-g mixograms within a cultivar were essentially equal. A mixogram time-to-peak difference of 0.276 min between two single values is significant at $P = 0.05$.

Mixing Time to Peak Series

When mixing time varied from about 6 to 1 5/8 min (Table III, Fig. 3), overall mixograms and times to peaks for the 5- and 10-g mixographs were comparable for each of the five mixing requirement levels.

Mixogram time to peak of a flour blend (Table III, top) generally is a function of the mixogram peak times of the component flours and their percentages in the blend.

Flour Protein Content Series

When flour protein content varied from 18.6 to 8.7% (Table III, Fig. 4), overall mixograms and their times to peaks for the 5- and 10-g mixographs were comparable for each of the five protein content levels.

Again, mixogram time-to-peak of a flour blend (Table III, bottom) is a function of the mixogram peak times and percentages of component flours in the blend.

The Mixograph and Functional (Breadmaking) Properties

Either the 5- or 10-g mixograph is a candidate for the single most useful instrument for determination and prediction of functional (breadmaking) properties (Table IV) of early generation plant breeders' lines. Table IV is a major revision of a similar table presented by Finney and Shogren (1972).

ACKNOWLEDGMENTS

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