EFFECT OF SPRING SETTINGS AND ABSORPTION ON MIXOGRAMS FOR MEASURING DOUGH CHARACTERISTICS[1]

W. C. SHUEY[2] AND K. A. GILLES[3]

ABSTRACT

Thirty-one different wheat varieties, ranging in protein content from 13.8 to 15.6%, averaging 14.6%, were tested on a mixograph at spring settings of 6, 8, 10, and 12 with a corresponding change in absorption of 80.0, 73.3, 66.7, and 60.0%, respectively. Some physical characteristics of the mixograph were determined. Three readings of the mixograms – time to peak, height of curve, and the angle of breakdown – were determined and correlated with baking characteristics. The results showed that flours respond differently to changes made on the mixograph. These changes suggest that flours from wide genetic backgrounds fall into two or possibly three broad classifications.

The Recording Dough Mixer and the Mixograph[4] which evolved from it have been extensively used as tools in quality testing (1,2,3,4) as well as in the study of the influence of varietal and environmental effects (5,6,7). Papers have been written describing mixograms and methods of appraising them (8,9). Studies have been made, relating

[1]Manuscript received June 7, 1965. Presented at the 50th annual meeting, Kansas City, Mo., April 1965.

[2]Research Technologist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Hard Red Spring and Durum Wheat Quality Laboratory, Cereal Technology Department, North Dakota State University, Fargo.

[3]Chairman, Department of Cereal Technology, North Dakota State University, Fargo.

[4]Mention of firm names or trade products does not imply that they are endorsed or recommended by the United States Department of Agriculture over other firms or similar products not mentioned.

the various mixogram patterns to such baking characteristics as loaf volume and baking ingredients (10–14).

Even with the extensive use of the mixograph, little information is available about the physical response of the instrument. Harris (15) has reported a study on the effect of different operators on evaluating mixograms. Harris and co-workers (16) also studied the effect that temperature had on the mixograms. In this same source, Harris (16), as well as Swanson and Andrews (17), gives some information regarding the influence of absorption on the mixogram.

Because of limited available information, the study had two objectives:

1) To determine some of the physical characteristics of the mixograph and their influence on the mixogram; and
2) To see whether these effects due to the characteristics could be employed advantageously in testing flours for obtaining additional information for quality evaluation.

Materials and Methods

Flours of 29 different wheat varieties from the 1963 crop grown in six states at 13 locations were blended by varieties. The average flour extraction of the blends ranged from 58.9 to 66.8%, averaging 63.4%; average flour protein of the blends ranged from 13.8 to 15.6%, averaging 14.6%.

The samples were milled in a Brabender Quadrumat Jr. Mill with a modified flow, clothing the drum sieve with a No. 18 wire. The throughs of the No. 18 wire were sifted on a Strand Sifter with a No. 60 Tyler Mesh Sieve. The flour was the throughs of the No. 60 wire.

The moisture content of all flour samples was adjusted to 14.0%.

The flours were tested on a mixograph at spring settings of 6, 8, 10, and 12, with a corresponding change in absorption of 80.0, 73.3, 66.7, and 60.0%, respectively.

The flour weight was constant for each test at 30 g. The temperature was maintained at 25° ± 0.1°C.

Three readings were determined from the curve: 1) the height in cm. of the center of the curve at maximum height (H); 2) the length in cm. of the curve to maximum height (L) or peak; and 3) the angle of breakdown in degrees of the curve (A) after the peak. A representative curve is shown in Fig. 1.

The baking formula used was as follows:

100% flour	3% milk (NFDM)
2% salt	3% yeast
5% sugar	2% shortening

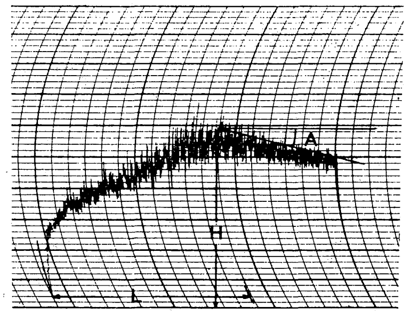

Fig. 1. Sample mixogram with readings shown. H, maximum height in cm. of the curve; L, length in cm. to maximum height or peak; A, angle of breakdown in degrees of curve after maximum height.

The dough was mixed to development in a National Manufacturing Micro mixer, using 25 g. of flour. A straight-dough procedure of 105 min. to first punch, 45 min. to second punch, 30 min. to pan, and 55 min. proof time was used. The dough was baked in a small pup-loaf pan for 20 min. at 415°F. in a revolving-shelf oven.

Results and Discussion

Mixograph characteristics were studied to determine the relation of four spring settings and the torque. The torque was calculated for

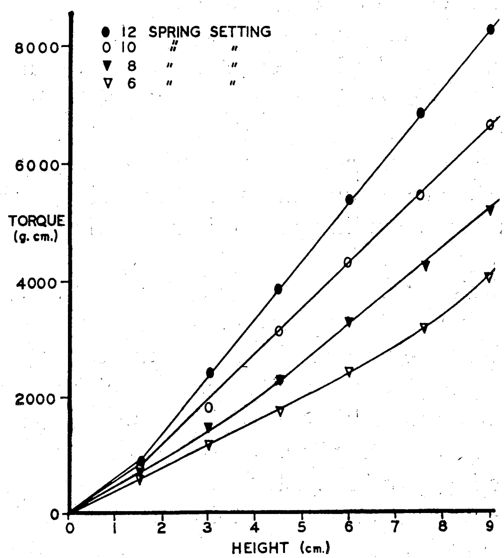

Fig. 2. Torque required to displace pen on chart to a height of 1.5, 3.0, 4.5, 6.0, 7.6, and 9.0 cm. for spring settings of ●, 12; ○, 10; ▼, 8; ▽, 6.

each spring setting of 6, 8, 10, and 12 by measuring the weight required to displace the pen on the chart to a height of 1.5, 3.0, 4.5, 6.0, 7.6, and 9.0 cm. Figure 2 shows the torque required to displace the pen at a given height for the spring settings studied.

The lower spring settings of 6 and 8 show a curvilinear relation, with the greatest curvature for the spring setting of 6. A straight line was found for spring settings of 10 and 12 from 1.5 to 9.0 cm. The same weight of 58 g. was required to displace the pen 1.5 cm. for all four spring settings. At this displacement of 1.5 cm. there was no tension on the spring; therefore, only the weight of the spring and distance that the spring was attached from the pivot of the arm were factors. This accounted for the curvilinear relation at the lower spring settings, since the weight of the spring tended to overcome the weight required to move the pen, and there was only partial tension on the spring. Thus, two forces were involved, one constant, the other progressively increasing. At the higher spring settings after the first displacement of 1.5 cm., sufficient tension was placed on the spring so that the force was proportional to the characteristic of the spring.

This effect is further demonstrated in Fig. 3; the log of the torque

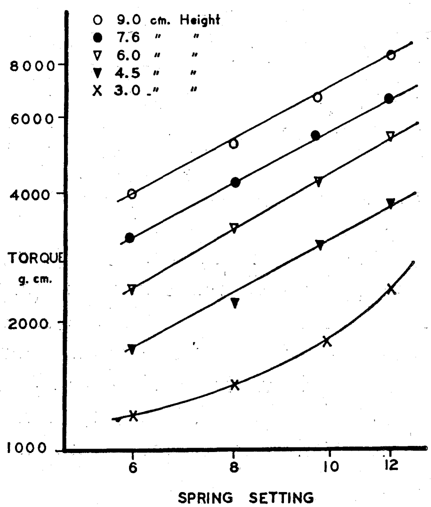

Fig. 3. Log of torque required *vs.* log of spring settings for given pen displacements on chart, ○, 9.0; ●, 7.6; ▽, 6.0; ▼, 4.5; ×, 3.0 cm., respectively.

was plotted against the log of the spring setting for a given set of displacements. Since the weight at 1.5-cm. displacement was the same for each setting, the straight line found must be a function primarily of the radius of the arc. A curvilinear relation was found for the

3.0-cm. displacement, and the points were at a much steeper angle than for the 1.5-cm. series. Parallel straight lines were found for the remaining displacements with slopes of 1.11. The slope of the line for the 1.5-cm. displacement was +0.53.

Thus, a transition took place between the 1.5- and 4.5-cm. displacement to give rise to a family of curves which had the same slope from 4.5 to 9.0 cm. This transition occurred when the tension on the spring was sufficient to overcome the "sag weight" of the spring.

The nonlinearity of the spring tension was checked independently of the mixograph. The extension of the spring was measured by suspending the spring vertically at one end and adding weights to the other. The data given in Fig. 4 show that the spring tension became linear above 150 g., verifying results given in Figs. 2 and 3.

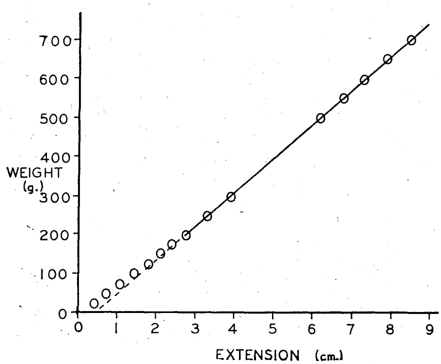

Fig. 4. Extension characteristic of mixograph spring.

Because the samples were run at a constant absorption for the given spring settings, adjustments were made in the absorption necessary to center the curve at 7.6 cm. from the base line. This value (7.6 cm.) was the average height of all of the tests. The average corrected absorption for each setting was determined. The spring setting was plotted against the average absorption. As shown in Fig. 5, the straight line obtained indicated that the absorptions from mixograms are proportional to the spring settings.

The log of the reciprocal of the absorption was found to be linearly related to the torque (Fig. 6). This tends to corroborate the findings of the data given in Fig. 2.

To study further the effect of spring setting and absorption on mixogram patterns, the length of the curve (L) or peak was plotted against the percent absorption (Fig. 7). Note that the points appeared to fan out at the higher absorptions. The averages for each series of

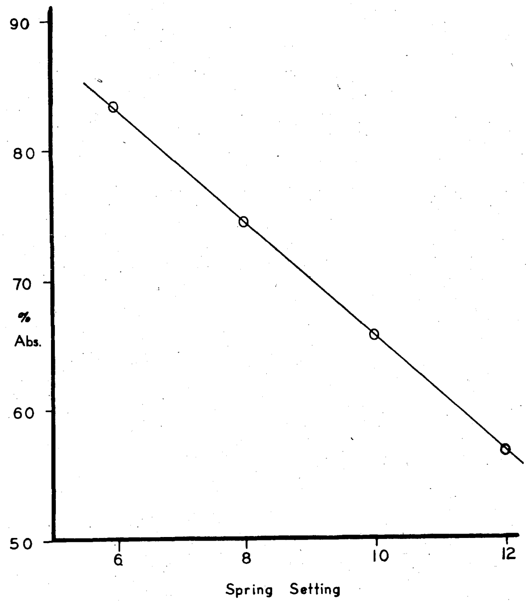

Fig. 5. Average absorption for given spring settings *vs.* spring setting.

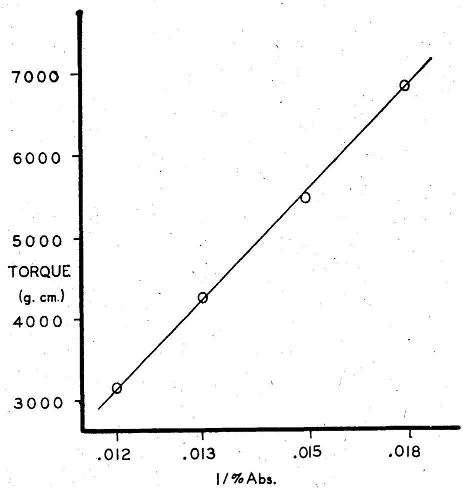

Fig. 6. Torque *vs.* log of the reciprocal of average absorption for given spring settings.

spring settings are shown by the heavy solid dots through which a curve was drawn. Not only did the range in the length become greater as the spring setting decreased or the absorption increased, but the

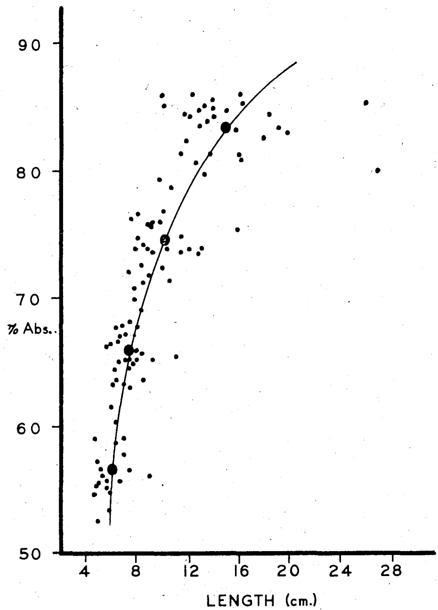

Fig. 7. Percent absorption *vs.* length of curve to maximum height, L (peak). Small dots, individual samples; large dots, average for given spring settings.

average results indicated that a curvilinear relation exists although the correlation coefficient was +0.73. The range in length for the 6 and 12 spring settings were 17.0 and 4.7 cm., respectively. This verified the observations of Swanson and Andrews (17), which showed that the absorption influences the length of the curve, though they did not change the spring setting in their study.

Straight lines, found when the logarithm of the length of the curve was plotted against the absorption (Fig. 8), demonstrated that develop-

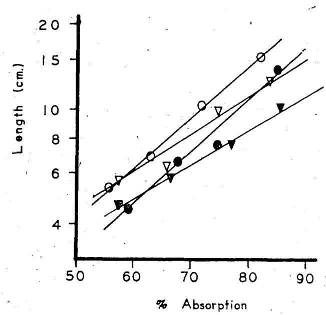

Fig. 8. Examples of the plot of the log of the length of the curve, L (peak), *vs.* absorption of four different flour samples.

ment of a dough in this type of mixer was not directly proportional to the absorption, but that it did vary with absorption. The slopes of the lines varied, depending upon the variety; there appeared to be three different families of curves from the slopes. Studies are now being made to relate the slopes of these lines to quality or some specific characteristic of the sample.

Another striking observation noted from these data was the stepwise change in length of the curve with absorption. It was found that when the ΔL was plotted against the corresponding ΔAbs., a parabolic curve was obtained; however, the samples fell into two categories. Some of the samples gave parabolas in which the focus was negative to the vertex, opening to the left (Fig. 9, A); in others the focus was positive to the vertex and opened to the right (Fig. 9, B). The equations for these

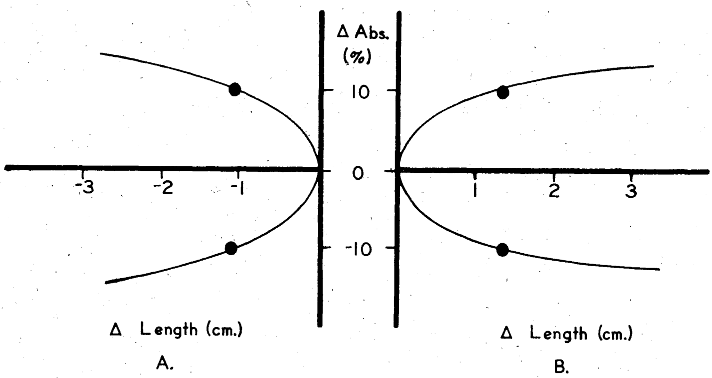

Fig. 9. Average parabolas obtained plotting Δ absorption *vs.* Δ length, L (peak).

two parabolas were, respectively, $y^2 = -0.91x$, and $y^2 = 0.71x$.

The formulas were not merely opposite in sign; they also contain different values which indicate that the two categories are distinctly different. It is speculated that this difference in response to changes in absorption could be related to the potential ability of the flour to respond to continuous breadmaking.

In Table I are given the correlation coefficients of various mixogram readings and baking results at the different spring settings. Only a few of the more significant correlations are given. From the data presented, it may be concluded that:

1. The angle of breakdown was affected by mixogram absorption.

2. The angle of breakdown was affected by the height of the mixogram but decreased with decreasing absorption.

3. The mixogram absorption was significantly correlated with the

TABLE I

Correlation Coefficients of Various Mixogram Readings and Baking Results at Different Spring Settings and Absorptions

Factors [a]	Spring Setting and Absorption			
	6 83.5	8 74.4	10 65.8	12 56.6
A vs. H	0.75	0.61	0.55	0.06
A *vs.* M.Ab.	0.54	0.60	0.45	0.41
B.Ab. *vs.* M.Ab.	...	0.47	0.41	...
B.Ab. *vs.* H	0.45	0.47	0.43	...
Mix time *vs.* L	0.64	0.69	0.69	0.72
Mix time *vs.* M.Ab.	...	0.64	0.52	0.55

[a] A = breakdown angle; H = center of curve at maximum height, in cm.; M.Ab. = mixogram absorption required to center curve at 7.6 cm. at H; B.Ab. = bake absorption; mix time = bake mixing time; L = length of curve to H, in cm.

baking absorption only at spring settings of 8 and 10. (This might be expected, since similar mixers are used for both.)

4. The baking absorption was correlated equally well with the height of the mixogram as with the mixogram absorption, with the exception of the data for a spring setting of 6.

5. Bake mixing time and length of mixogram (peak) had the highest correlation of the data recorded.

6. The relation between length and mixing time tends to be more highly significant with increased spring setting.

7. The bake mixing time was related to the absorption of the mixogram for all of the spring settings except 6. These results would indicate that the mixing time is related to the water absorption capacity of the sample that is being tested.

The results of this study show that the different flours responded differently to changes made on the mixograph. These changes indicate that flours from a wide variation in genetic background fall into at least two broad classifications and possibly three. The use of a given spring setting for a series of flours may well rate the flours in a different order from that with a different spring setting. Doubtless, reasons for these inconsistencies are related to the curvilinear responses of the mixograph itself, spring setting, and torque, and to the fact that different flours will respond differently to a given set of conditions. Therefore, when the mixograph is used to evaluate flour quality, much more information can be ascertained by the use of two spring settings and absorptions.

These results show that it is imperative, when comparing the mixograms of two or more mixographs, that characteristics be determined. The mixographs must be adjusted to have like characteristics before the results can be compared.

Literature Cited

1. SWANSON, C. O., and WORKING, E. B. Testing the quality of flour by the recording dough mixer. Cereal Chem. **10:** 1–29 (1933).
2. JOHNSON, J. A., and SWANSON, C. O. The testing of wheat quality by recording dough mixer curves obtained from sifted wheat meals. Cereal Chem. **19:** 216–229 (1942).
3. MORRIS, V. H., BODE, C. E., and HEIZER, H. K. The use of the mixogram in evaluating quality in soft wheat varieties. Cereal Chem. **21:** 49–57 (1944).
4. SIBBITT, L. D., and HARRIS, R. H. Comparison between some properties of mixograms from flour and unsifted whole wheat meal. Cereal Chem. **22:** 531–538 (1945).
5. SWANSON, C. O. Variations in dough-development curves. Cereal Chem. **16:** 625–643 (1939).
6. SWANSON, C. O. Effects of moisture on the physical and other properties of wheat. II. Wetting during harvest. Cereal Chem. **20:** 43–61 (1943).
7. HARRIS, R. H., SIBBITT, L. D., and ELLEDGE, MURIEL. Varietal, station, and seasonal effects upon some properties of mixograms made from hard red spring wheat flours by various mixing methods. Cereal Chem. **21:** 38–48 (1944).
8. SWANSON, C. O., and JOHNSON, J. A. Description of mixograms. Cereal Chem. **20:** 39–42 (1943).
9. ZALIK, S., and OSTAFICHUK, M. Note on a method of appraising mixogram data. Cereal Chem. **37:** 105–106 (1960).
10. HARRIS, R. H., SIBBITT, L. D., and BANASIK, O. The prediction of loaf volume of hard red spring wheat flours from some properties of mixograms. Cereal Chem. **20:** 211–223 (1943).
11. JOHNSON, J. A., SWANSON, C. O., and BAYFIELD, E. G. The correlation of mixograms with baking results. Cereal Chem. **20:** 625–644 (1943).
12. SWANSON, C. O., and ANDREWS, A. C. Factors which influence the physical properties of dough. V. Gluten protein as the main factor affecting the pattern of mixograms. Cereal Chem. **20:** 61–78 (1943).
13. AITKEN, T. R., and FISHER, M. H. Mixing tolerances of varieties of hard red spring wheat. Cereal Chem. **22:** 392–406 (1945).
14. JOHNSON, J. A., and SWANSON, C. O. Effect of fermentation, rest periods, and formula ingredients on mixogram patterns. Cereal Chem. **22:** 204–214 (1945).
15. HARRIS, R. H. The effect of different operators on the evaluation of mixograms. Cereal Chem. **20:** 739–744 (1943).
16. HARRIS, R. H., SIBBITT, L. D., and SCOTT, G. M. The effect of temperature differences on some mixogram properties of hard red spring wheat flours. Cereal Chem. **21:** 374–385 (1944).
17. SWANSON, C. O., and ANDREWS, A. C. Dough development and mechanical gluten dispersion in relation to amount of mixing and to the flour-water ratio. Cereal Chem. **22:** 60–75 (1945).