Use of the Alveograph for Quality Evaluation of Hard Red Spring Wheat[1]

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ABSTRACT

An investigation of the Chopin alveograph for use in quality evaluation of hard red spring (HRS) wheats was undertaken. In most cases, the correlations of alveogram values with loaf volume and flour protein were low and nonsignificant. Various modifications of the standard recommended alveograph method were attempted. However, no improvement in the correlation of alveogram values and loaf volume was obtained. With the use of 5 p.p.m. of sodium bisulfite, the S and W values of the alveogram curve were found to be significantly correlated with loaf volume but the correlations were low. However, when the same concentrations of sodium bisulfite were utilized on samples of a different crop year, low and nonsignificant correlations were obtained. With potassium iodate, the correlations of alveogram values with loaf volume were also low and nonsignificant. However, it was found that this instrument was able to detect the effect of as little as 3.0 p.p.m. of potassium iodate in HRS wheat dough. The apparatus also was able to detect differences in physical properties which existed between samples which differed little in protein content or in loaf volume.

Chopin (1), who invented the alveograph, reported that the only mechanical test that was comparable with the process involved in the raising of bread consisted of drawing out a sample of dough from a compact state into a sheet which was stretched to the breaking limit. Measurements were made to determine the extent to which a dough might be stretched and also of the tensile strength during the process. Chopin suggested that the test should be performed upon the dough and not upon the gluten, as the latter's texture was changed by washing.

Scott Blair and Potel (2) suggested that under the standard conditions of the Chopin test, the P value, which indicated height of the curve, should be a measure of the water-absorbing capacity of the flour, since this value is related to viscosity.

In an investigation of the effect of protein and grade on farinogram, extensogram, and alveogram measurements, Aitken et al. (3,4) reported highly significant correlations between the L and W alveogram values and either protein content or loaf volume. They concluded also that the length of the alveogram curve was related to the extensibility of the dough. The height of the curve appeared to be associated with the stiffness, shortness, and tightness of the dough, whereas the W value was reported to be the best measure of resistance to extension.

Amos (5), from a study on the rheological methods used in milling and baking, concluded that the height of the alveogram peak could be used as an index of stability of the dough. The length of the base of the curve was a measure of extensibility, and the area under the curve was reported to be a measure of its strength.

Bennett and Coppock (6) described a new technique for the Chopin alveograph

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by which it became possible to use it to detect the effects of improvers on flour. This procedure involved keeping the dough in bulk for 3 hr. at constant temperature, after which test pieces were weighed, molded, and tested. It was reported that, when the standard method was used, there was no significant change with a dough containing as much as 0.006% bromate (60 p.p.m.). The method utilizing the molding step could detect as little as 0.0002% bromate (2 p.p.m.) and levels beyond 0.001% bromate (10 p.p.m.) were too high for measurement.

The purpose of this study was to determine if the Chopin alveograph could be used for quality evaluation of hard red spring wheat varieties. The standard method was initially utilized. Modifications in the alveograph method included an investigation of salt concentration, mixing time, absorption, rest period, type of mixer, and oxidizing and reducing agents. These modifications were attempted to ascertain if changes in the procedure would improve the use of the instruments for quality evaluation purposes.

MATERIALS AND METHODS

Wheat Samples

Thirteen Commercial Size Plot (CSP) samples of hard red spring (HRS) wheat grown at five different locations during 1968 and 1969 crop years were utilized for this study. Included were 11 conventional and two semidwarf samples. These samples were milled on a pilot Miag mill according to the method of Shuey and Gilles (7).

Standard Alveograph Method

The standard recommended alveograph method (8) was employed initially to determine its usefulness for quality evaluation purposes. Three measurements were made on the mean alveograph curve: the height of the curve (P), which measures the pressure applied during inflation and indicates the tenacity of the dough; the length of the curve (L), which measures the extensibility of the dough from the first application of pressure to the point where the surface of the bubble ruptures; and the area under the curve (S), which indicates strength of the dough. A minimum of three determinations was performed on each sample before L, S, and W values were accepted. With the aid of the G value, a value W was computed using the formula

$$W = \frac{K \times C \times S.}{L}$$

K is a constant (manometer correction coefficient) and is equal to 1.1. C is a value associated with the G value and is obtained from a table supplied with the alveograph. G is the square root of the volume of the air (in $cm.^3$) used to blow the bubble, and S is the average area in $cm.^2$ under the curve. The W value indicates the mechanical work in 10^3 ergs per g. of dough used to blow the bubble. This value is indicative of the overall strength of the gluten.

The various values obtained were correlated with flour protein and loaf volume.

Modifications in the Alveograph Method

To examine various factors in the recommended alveograph method, three samples of HRS wheat flour with protein contents ranging from 11.6 to 16.6% and loaf volumes of 675 to 930 cc. were selected.

The following modifications in the procedure were attempted:

Effect of Salt Concentration. Concentrations of 0.0, 0.5, 1.0, 1.5, 2.0, and 2.5% were used. The remainder of the procedure was similar to the standard method.

Effect of Different Rest Periods. Rest periods of 15, 18, 21, and 24 min. were studied. The remaining procedure was similar to the standard method with the exception that 1.5% salt concentration on a flour basis was used.

Effect of Different Water Absorptions. Water absorptions of 46.0, 48.0, 50.0, 52.0, and 54.0% were utilized with 1.5% salt concentration and 15-min. rest periods.

Effect of Different Mixing Times. Mixing times of 6, 8, 10, 12, and 15 min. were examined. Salt (1.5%), a 15-min. rest period, and a 50% absorption were used for this study.

Effect of a Different Mixer. A National mixer was used to replace the alveograph mixer for mixing. The alveograph mixer, however, was still used for extrusion. Mixing was conducted for 1.0, 1.5, 2.0, 2.5, and 3.0 min. An absorption of 50%, a salt concentration of 1.5%, and a 15-min. rest period were used.

Effect of Oxidizing and Reducing Agents. The incorporation of 3.0 p.p.m. of potassium iodate and 5.0, 10.0, and 15.0 p.p.m. of sodium bisulfite in the dough was studied. The solution of these chemicals was incorporated during the mixing. A 50% absorption, 8.0-min. mix time, 15-min. rest period, and 0.15% salt concentration were used.

Modified Alveograph Method Adopted

The modified procedure adopted for analysis of the 13 CSP samples mentioned previously included several modifications based on the results of the study under part B. Flour (250 g.) at 14% moisture basis, 50% absorption, 1.5% sodium chloride, 8.0 min. mixing time in alveograph mixer at 25°C., and a 15-min. rest period at 25°C. were the conditions utilized. The operation of the instrument was identical to that supplied by the manufacturer (8).

The same measurements were obtained using the modified method as were obtained using the standard recommended method.

The results were correlated with flour protein and loaf volume.

RESULTS AND DISCUSSION

Standard Alveograph Method

Using the standard alveograph method for a series of CSP samples, the correlation coefficients of alveogram values with flour protein and loaf volume shown in Table I were obtained.

The only significant correlation was between loaf volume and alveogram P value. The remainder of the correlations were all nonsignificant.

Modifications in Standard Alveograph Method

Since the correlations obtained with the standard alveograph method were insufficient to be used for evaluating flour quality of HRS wheats, various modifications of the procedure were attempted to ascertain optimum conditions for performing alveograph studies under which a high correlation could be

TABLE I. RELATION BETWEEN ALVEOGRAM VALUES (STANDARD PROCEDURE) AND LOAF VOLUME AND FLOUR PROTEIN

	Correlation Coefficient[a]	
	Loaf volume vs.	Flour protein vs.
Alveogram W value	− 0.450	0.203
Alveogram S value	− 0.292	0.190
Alveogram P value	− 0.610**	0.183

[a]Number of samples (N) = 18.

obtained. The treatments examined included different salt concentrations, absorption, mixing time, rest period, and different types of mixers. Scatter diagrams were prepared for all the data obtained. The alveogram values for each treatment investigated were plotted against loaf volume. From such plots, it was found that 1.5% salt concentration on a flour basis, a 15-min. rest period at 25°C., 8 min. of mixing at 25°C., and 50% absorption at 14% moisture basis gave the best results.

In one experiment, the dough was mixed in a National mixer for different times and then extruded in the alveograph mixer, but no significant results were obtained.

TABLE II. RELATION BETWEEN ALVEOGRAM VALUES (MODIFIED PROCEDURE) AND LOAF VOLUME

	Correlation Coefficient[a] Loaf Volume vs.
Alveogram W value	0.279
Alveogram S value	0.269
Alveogram P value	0.231
Alveogram L value	0.066

[a]Number of samples (N) = 18.

TABLE III. COMPARISON OF FLOUR PROTEIN IN (N X 5.7) WITH ALVEOGRAM W VALUE

Flour Protein %	W Value X 10^3 ergs
13.0	351
13.1	247
13.6	309
13.6	255
13.8	255
14.1	282

TABLE IV. COMPARISON OF LOAF VOLUME WITH ALVEOGRAM W VALUE

Loaf Volume cc.	W Value X 10^3 ergs
860	282
845	351
840	294
825	255
820	309
805	265

However, it was noticed that as the mixing time (National mixer) was increased, the height of the curve in all three varieties increased, and the length of the curve, W, and S values decreased. However, when the alveograph mixer was used, all the alveogram values decreased with an increase in mixing time. Similarly, with increasing absorption, the W value, area under the curve S, and the height of the curve P decreased while the length of the curve increased.

With different salt concentrations, the three varieties responded differently. The highest P values were obtained with the variety which had the highest protein content (16.6%). The lowest protein-containing variety (11.6%) gave the lowest curve height.

Modified Alveograph Method Adopted

Once the optimum conditions were established, the CSP samples already investigated by the standard alveograph method were studied once more using the modified alveograph method. The correlation coefficients of alveogram data thus obtained with loaf volume are shown in Table II.

These results show that the modified method did not give better correlations than the standard recommended method. These data revealed also that none of the alveograph values could be used to evaluate baking quality of HRS wheats. However, the results revealed that the apparatus was able to demonstrate differences in physical properties which existed between samples, although the same samples differed very little in protein content or in loaf volume. The results of these observations are shown in Tables III and IV. In general, though the results showed wide differences between certain varieties and treatments, none of the alveograph values were related highly to flour protein or loaf volume.

The effect of oxidizing and reducing agents on the alveogram properties indicated that with potassium iodate treatment, except for the length of the curve which showed a decreasing trend, the remaining alveogram values, that is, P, S, and W, increased. Effects of potassium iodate and sodium bisulfite upon correlation coefficients between loaf volume and modified procedure alveogram measurements are shown in Table V.

The inclusion of 3.0 p.p.m. potassium iodate did not result in significant correlations; however, using different concentrations of sodium bisulfite an improvement was noted in the relation between W and S alveogram values and loaf volume.

TABLE V. RELATION BETWEEN ALVEOGRAM VALUES (MODIFIED PROCEDURE) AND LOAF VOLUME

	Correlation Coefficients[a]			
	Sodium bisulfite			Potassium iodate
Loaf Volume vs.	5.0 p.p.m.	10 p.p.m.	15 p.p.m.	3.0 p.p.m.
Alveogram W value	0.556*	0.407	0.213	0.315
Alveogram S value	0.652*	0.447	0.318	0.411
Alveogram P value	0.206	0.033	0.324	− 0.086

[a]Number of samples (N) = 13.

When the modified method was used with the sodium bisulfite concentrations shown in Table V on a series of 1969 CSP samples, poor correlations were obtained at all levels. This indicates the requirements for flour from year to year will vary and modifications in the alveograph procedure would be necessary if such an instrument were to be used for quality evaluation purposes.

In the sodium bisulfite study, it was noticed that the alveogram values P, S, and W (Figs. 1, 2, and 3) increased with the use of sodium bisulfite when compared to the control, indicating that the dough, instead of getting slack, became tough. A possible explanation for these results might be the splitting of the gluten molecule into small chains because of the reduction of the disulfide bonds during mixing followed by reorganization of these small chains into long chains during the rest

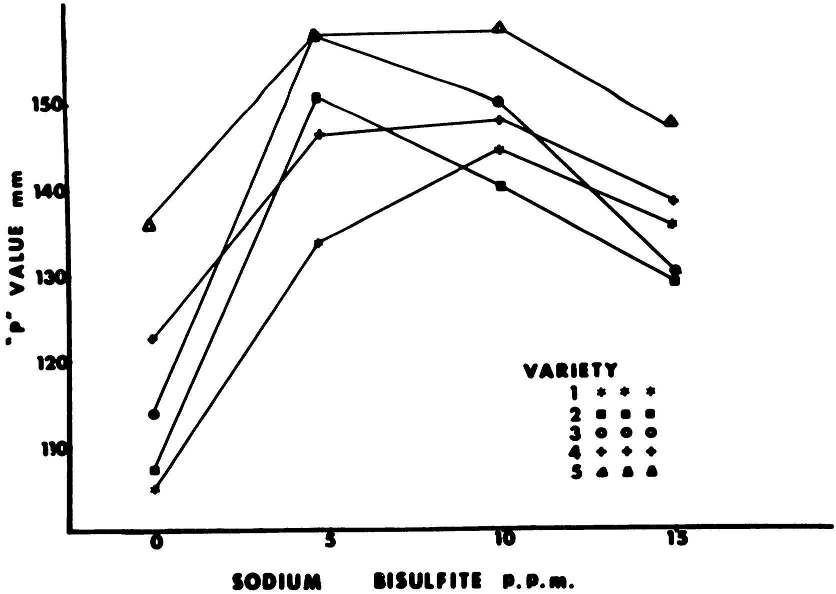

Fig. 1. Effect of sodium bisulfite on the alveogram P value of five HRS wheat varieties.

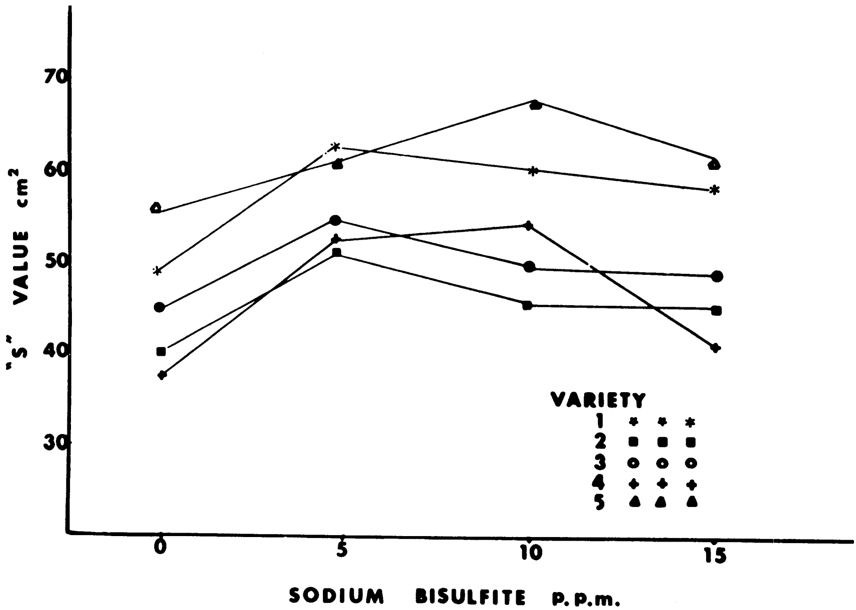

Fig. 2. Effect of sodium bisulfite on the alveogram S value of five HRS wheat varieties.

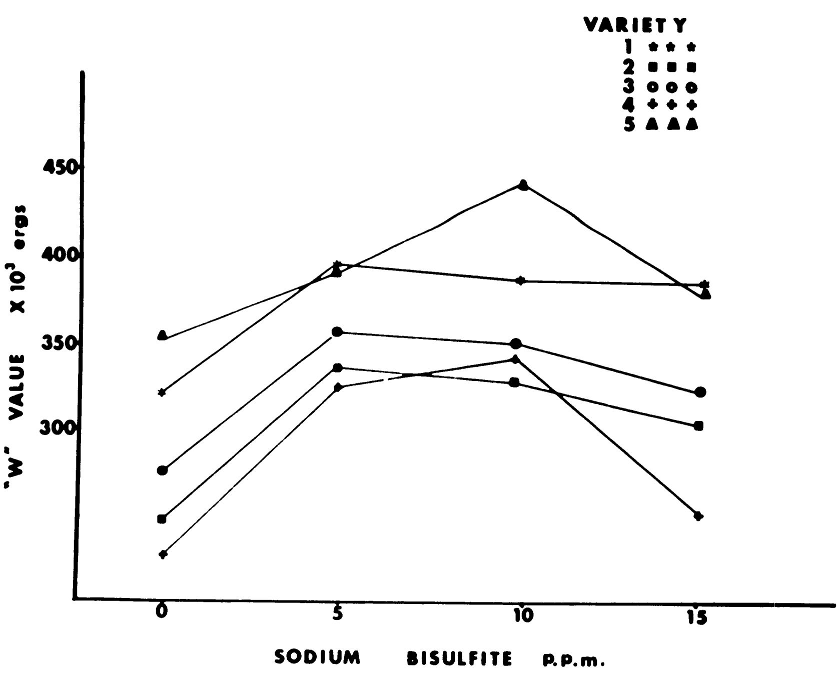

Fig. 3. Effect of sodium bisulfite on the alveogram W value of five HRS wheat varieties.

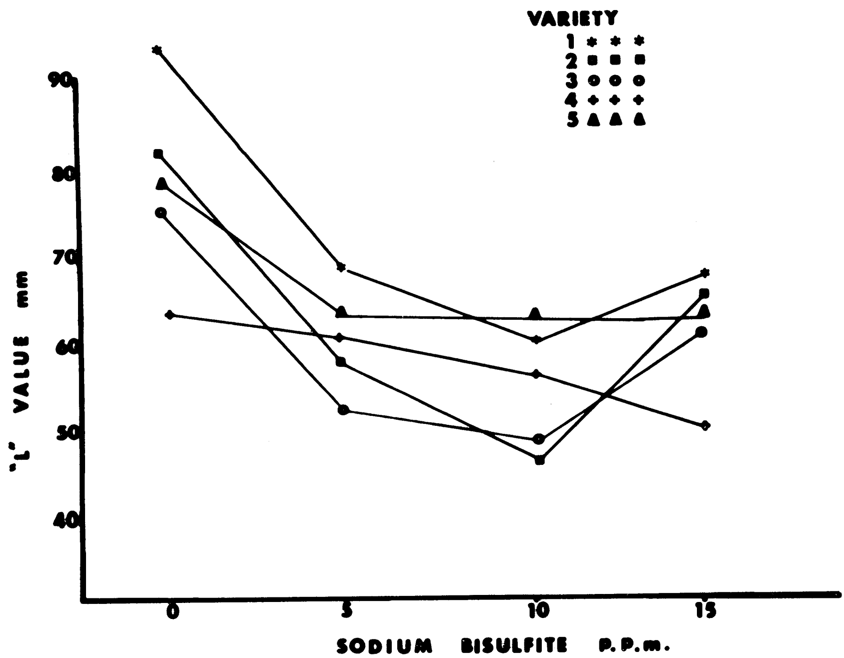

Fig. 4. Effect of sodium bisultife on the alveogram L value of five HRS wheat varieties.

period, thereby increasing the strength of the dough. The length of the curve in all cases decreased (Fig. 4). However, when the three values (P, S, and W) were compared with the three treatments of sodium bisulfite, a decreasing trend was noticed as the sodium bisulfite concentration was increased.

Discussion

Bailey and LeVesconte (9) reported that prolonged mixing in the Chopin extensimeter decreased the extensibility of the dough (length of curve). The present study supported the findings of the above workers (9) when the mixing was performed in a National mixer. However, when the alveograph mixer was used for mixing, there was a slight decreasing trend in extensibility of the dough with mixing in the case of certain varieties.

Aitken et al. (3) reported very high and significant correlations of W and L and flour protein and loaf volume. The results of the current investigation indicated that most of the correlation coefficients were low and insignificant and did not support Aitken et al. (3).

The results of the present study disagree with Amos (5), who reported that the area under the curve was a good indication of the baking strength of flour. It was found in this study that the correlation of the area under the curve S with loaf volume was in most cases lower than the correlation of W and P values. However, the study on the effect of oxidizing and reducing agents revealed that the S value showed a better correlation with loaf volume than either the P or W value.

Bennett and Coppock (6) described a new procedure for studying the effect of bromate on the alveogram curve. This method involved a 3-hr. rest period after adding the improver and molding the dough before the actual test. They reported that using this technique it was possible to detect the effect of as little as 0.0002% (2.0 p.p.m.) of bromate while with the standard method no significant change was noticed with as much as 0.006% (60 p.p.m.) bromate. The results of the present work using potassium iodate differ from those of the above workers (6). It was found that as little as 3.0 p.p.m. of iodate had a significant effect on the alveogram obtained using the standard method. With 5.0 p.p.m., the dough was too tough to get measurable alveograms. A possible reason for the discrepancy in results was that the above workers used soft wheats and a mixture of soft and spring wheats in their study. Also, the potassium bromate was probably less effective since it is a weaker oxidizing agent than potassium iodate.

From the results of the current study, it is concluded that the alveograph is not a suitable apparatus for use in quality evaluation of HRS wheats.

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Literature Cited

1. CHOPIN, M. Determination of baking value of wheat by measure of specific energy of deformation of dough. Cereal Chem. 4: 1 (1927).
2. SCOTT BLAIR, G. W., and POTEL, P. A preliminary study of the physical significance of certain properties measured by the Chopin extensimeter for testing flour doughs. Cereal Chem. 14: 257 (1937).
3. AITKEN, T. R., FISHER, M. H., and ANDERSON, J. A. Effect of protein content and grade on farinograms, extensograms, and alveograms. Cereal Chem. 21: 465 (1944).
4. AITKEN, T. R., FISHER, M. H., and ANDERSON, J. A. Reproducibility studies and some effects of technique on extensograms and alveograms. Cereal Chem. 21: 489 (1944).
5. AMOS, A. J. Rheological methods in the milling and baking industry. Analyst 74: 392 (1949).
6. BENNETT, R., and COPPOCK, J. B. M. Measuring the physical characteristics of flour. A method of using the Chopin Alveograph to detect the effect of flour improvers. J. Sci. Food Agr. 3: 297 (1952).
7. SHUEY, W. C., and GILLES, K. A. Laboratory scale commercial mill. (Abstr.) Cereal Sci. Today 12: No. 146 (1967).
8. SYSTEM, CHOPIN M. Instructions for using the Alveograph apparatus for mechanically testing flour doughs. M. Chopin, et cie: 5-Rue Escudier, Boulogne, Sur-Seine(Sein) France (1960).
9. BAILEY, C. H., and LeVESCONTE, A. M. Physical tests of flour quality with Chopin Extensimeter. Cereal Chem. 1: 38 (1924).

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