

SEDIMENTATION VALUE AS AN INDEX OF DOUGH-MIXING CHARACTERISTICS IN EARLY-GENERATION WHEAT SELECTIONS¹

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ABSTRACT

Mixogram curves were made and sedimentation values determined on flours from 159 samples of hard red spring wheat representing F_3 -generation lines from a cross between a high-protein, strong-gluten variety, Conley, and a low-protein, weak-gluten strain, P.I. 56219-12, used for breeding purposes because of its sawfly resistance. In addition, two samples each of the parent wheats were used in the study. Sedimentation values of the strong and weak parent wheats were 69 and 26, respectively, and all but one of the F_3 -generation lines had values intermediate between these two extremes. Highly significant correlations were found between sedimentation values, mixing times, mixing tolerances, and weakening angles as determined from the mixograph curves. Correlations between protein content and these dough-mixing properties were low and not significant.

The sedimentation test may provide a useful and simple tool for making early-generation wheat selections on the basis of dough characteristics. By using a semimicro technique, it should be possible to apply the test to the wheat from individual plants.

Gluten quality is a particularly important factor to consider in breeding hard winter and spring wheats since varieties with weak gluten characteristics are unacceptable for the production of bread flour. Wheats having long mixing time usually are preferred, largely because mixing time is rather closely associated with mixing tolerance. Long mixing tolerance is in reality the most sought-after quality characteristic in hard wheat breeding programs in the United States.

Variation among wheats in gluten quality is for the most part genetically controlled, and the effectiveness of selection for desirable types depends upon evaluation procedures available. The lack of any satisfactory simple method for judging dough-making characteristics in early generations makes it necessary to carry many lines for additional generations. The efficiency with which high-quality wheats can be isolated from a hybrid lot of material might be increased markedly through the development and use of suitable methods for judging quality in early generations, such as the F_3 generation.

The micromilling technique of Seeborg and Barmore (6) makes it

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possible to judge certain important milling characteristics on 5 g. of wheat. Protein content can be determined on 1 g. of wheat, or even on individual kernels if necessary. Gluten quality evaluation, however, is usually accomplished by means of baking tests or from a study of dough characteristics as determined with a recording dough mixer. Both of these procedures usually require a relatively large amount of wheat and therefore cannot normally be applied to the early generations in the breeding program. It should be noted, however, that micromilling techniques have been developed by Geddes and Frisell (3) and by Finney and Yamazaki (2), and a micro-baking technique by Shogren and Shellenberger (8).

The purpose of this paper is to investigate the possible usefulness of the sedimentation test in wheat breeding for the purpose of selecting promising lines from early generations. The studies reported are confined to two parent wheats of widely different dough-making characteristics and 159 F_3 lines resulting from a cross between these varieties.

Materials and Methods

Wheat samples used for this study consisted of 159 F_3 lines taken from an unselected population from a cross between the variety Conley and the strain P.I. 56219-12 introduced from Portugal. Conley is a hard red spring wheat of long mixing time, long mixing tolerance, and excellent bread-baking strength. P.I. 56219-12 is a hard red spring wheat introduction useful for breeding purposes primarily because of its solid stem and consequent sawfly resistance (a characteristic not shared by Conley), but it is of relatively short mixing time and tolerance. Included also in the study were two samples of each parent variety, which in each case were grown in separate rod rows. All of the wheats were grown in the same plot at the North Central Experiment Station, Minot, North Dakota, in 1956. About 160 g. of each sample were available for milling.

The samples were tempered to a moisture content of 16% and milled to straight-grade flours on the Allis-Chalmers experimental flour mill. Because of the very small size of the samples, flour-yield data were considered to be of no particular significance.

Mixograms were made with the National Manufacturing Company's Mixograph. The weight of the flour used was 35 g. calculated to a 14.0% moisture basis. The absorptions used were calculated by use of the regression equation and according to the procedure described by Johnson *et al.* (4). All tests were made at temperatures within the range of 25°–27°C. Mixing time and weakening angle

were determined by the method of Johnson *et al.* (4). Mixing tolerance was determined as the horizontal distance between the centers of the ascending and descending parts of the mixogram through the bottom of the band at its peak point (see Fig. 1). Obviously these measurements are not completely objective, but they were all made in a uniform manner by the same experienced operator and should be reasonably comparable.

Sedimentation value was determined by the method of Zeleny (9) as modified by Pinckney *et al.* (5) and described in *Cereal Laboratory Methods* (1). The flour samples milled with the Allis-Chalmers experimental flour mill were used for the sedimentation tests. Specific sedimentation value was determined by dividing the sedimentation value by the percentage of protein in the flour, calculated to a 14.0% moisture basis. The sedimentation value is influenced both by quantity and "strength" of the gluten protein, while the specific sedimentation is essentially an index of gluten strength without regard to protein content.

Protein content was determined by the Kjeldahl method.

Results

Mixograms for one of the samples of each of the parent wheats are shown in Fig. 1. Some of the F_3 lines gave mixograms similar to those of each of the parents, but most of them gave mixograms intermediate in character.

The pertinent mixogram data as well as the sedimentation and protein data for the two parent wheats are shown in Table I.

The distribution of sedimentation values among the samples and the corresponding mixogram data by class averages are shown in Table II.

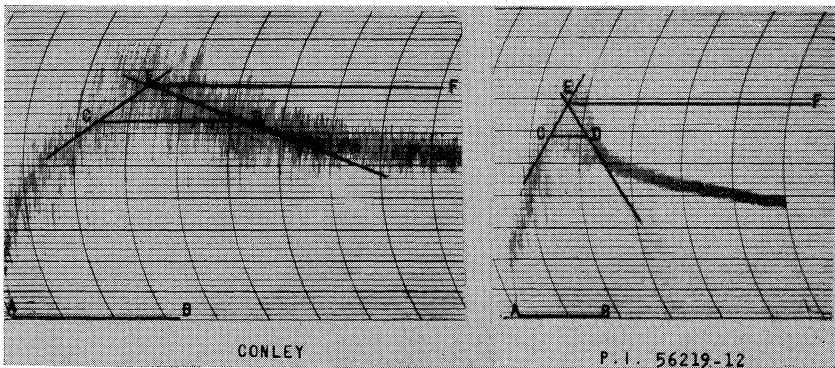


Fig. 1. Mixographs of parental wheats. AB = mixing time; CD = mixing tolerance; DEF = weakening angle.

The more important statistical relationships among mixogram, sedimentation, and protein data are shown in Table III.

TABLE I
MIXOGRAM CHARACTERISTICS, SEDIMENTATION, AND PROTEIN DATA FOR THE FLOURS FROM
THE TWO SAMPLES OF EACH OF THE PARENT WHEATS

| | CONLEY | | | P. I. 56219-12 | | |
|---------------------------|--------|------|------|----------------|------|------|
| | A | B | Av. | A | B | Av. |
| Mixing time, minutes | 3.25 | 3.00 | 3.12 | 1.75 | 1.50 | 1.62 |
| Mixing tolerance, minutes | 2.75 | 3.50 | 3.12 | 0.75 | 0.75 | 0.75 |
| Weakening angle, degrees | 20 | 32 | 26 | 58 | 55 | 56 |
| Sedimentation value | 69 | 69 | 69 | 26 | 26 | 26 |
| Specific sedimentation | 4.4 | 4.4 | 4.4 | 2.1 | 2.1 | 2.1 |
| Protein, % | 15.8 | 15.5 | 15.6 | 12.5 | 12.4 | 12.4 |

TABLE II
SEDIMENTATION VALUES AND THE DISTRIBUTION OF MIXOGRAM DATA BY CLASS AVERAGES
FOR 163 SAMPLES OF WHEAT REPRESENTING TWO SAMPLES EACH OF THE PARENT
WHEATS CONLEY AND P. I. 56219-12 AND 159 SAMPLES REPRESENTING F₃ LINES
OF THE CROSS

| SEDIMENTATION VALUE | NO. OF CASES | AV. MIXING TIME | AV. MIXING TOLERANCE | AV. WEAKENING ANGLE |
|------------------------|-----------------|--------------------|-------------------------|------------------------|
| | | <i>minutes</i> | <i>minutes</i> | <i>degrees</i> |
| 25-29 | 5 | 1.40 | 0.60 | 61 |
| 30-34 | 9 | 1.53 | 0.72 | 58 |
| 35-39 | 31 | 1.68 | 0.84 | 53 |
| 40-44 | 31 | 1.82 | 1.03 | 50 |
| 45-49 | 20 | 2.01 | 1.18 | 44 |
| 50-54 | 19 | 2.25 | 1.50 | 41 |
| 55-59 | 15 | 2.02 | 1.28 | 44 |
| 60-64 | 21 | 2.33 | 1.85 | 35 |
| 65-69 | 12 | 2.81 | 2.19 | 33 |

TABLE III
STATISTICAL ANALYSIS OF DATA

| FACTORS | CORRELATION COEFFICIENT | STANDARD ERROR OF ESTIMATE |
|---|----------------------------|----------------------------------|
| Sedimentation value vs. mixing time | 0.61** | 0.42 minutes |
| Sedimentation value vs. mixing tolerance | 0.74** | 0.38 minutes |
| Sedimentation value vs. weakening angle | -0.62** | 9.2° |
| Specific sedimentation vs. mixing time | 0.67** | 0.39 minutes |
| Specific sedimentation vs. mixing tolerance | 0.78** | 0.35 minutes |
| Specific sedimentation vs. weakening angle | -0.69** | 8.5° |
| Protein content vs. mixing time | -0.01 | 0.53 minutes |
| Protein content vs. mixing tolerance | 0.14 | 0.56 minutes |
| Protein content vs. weakening angle | 0.10 | 11.8° |
| Protein content vs. sedimentation value | 0.52** | 9.4 ml. |
| Mixing time vs. mixing tolerance | 0.80** | 0.33 minutes |

Discussion

Mixogram, sedimentation, and specific sedimentation values for the 159 F_3 -generation wheats all covered wide ranges, and almost all of the values fell at intermediate points between the high values of the Conley parent and the low values of the P. I. 56219-12 parent. Highly significant correlations were found between both sedimentation value and specific sedimentation value, on the one hand, and mixing time, mixing tolerance, and weakening angle on the other hand. Generally speaking, mixing time and mixing tolerance were closely associated, as evidenced by the high correlation between these two factors. The correlations between protein content and mixogram characteristics were low and not significant.

Of the 159 F_3 -generation wheats used in this study 17, or 11%, had mixing times of 2.75 minutes or over; and 19, or 12%, had mixing tolerances of 2.00 minutes or over. Thirty-one, or 19%, of the 159 wheats had sedimentation values of 60 or over. This small group of high-sedimentation wheats included 59% of all of the samples having long mixing times (2.75 minutes or over) and 79% of all of the samples having long mixing tolerances (2.00 minutes or over). It is also interesting to note that although 59% of the 159 F_3 -generation wheats had sedimentation values of less than 50, only three of the seventeen long-mixing-time wheats and none of the nineteen long-mixing-tolerance wheats fell into that group. Thus in this instance it would be possible to segregate reasonably well the great majority of the wheats with the most desirable mixogram characteristics by using the relatively simple sedimentation test as the basis for selection. More than half of the wheats could be eliminated on the basis of sedimentation values without sacrificing a single one of the wheats with long mixing tolerance.

Although complete segregation of the wheats with the most desirable mixogram characteristics obviously cannot be made by means of the sedimentation test, it is interesting to speculate as to whether the sedimentation test itself may not provide a more reliable guide for making wheat selections than does the mixograph or any other recording dough mixer. The data of Pinckney *et al.* (5) indicate that the sedimentation value is a more reliable index of bread loaf volume than is the farinogram. In a survey of the quality of wheats imported by several European countries over an 18-month period and reported by Shellenberger (7), the sedimentation value was found to be a better measure of bread-baking quality ("quality score") than was either protein content, valorimeter value (obtained by the farinograph), or "W" value (obtained by the alveograph).

A total of 361 shipments of wheat produced in 16 different countries was included in this survey.

The greatest advantage of the sedimentation test in evaluating early-generation lines in wheat-breeding programs may prove to be the very small amount of material required. At least 50 g. of wheat are required to obtain sufficient flour for the mixogram, while about 20 g. of wheat are sufficient for making a single sedimentation test by the established method. Preliminary experiments have been made which indicate that sedimentation tests may be made reliably by means of a semi-micro technique using only 2 g. of wheat. In these trials the standard sedimentation test procedure was used except that the size of the flour sample and of the portions of all reagents was reduced to one-tenth, and 10-ml. rather than 100-ml. graduated cylinders were used. Sedimentation values so obtained and multiplied by 10 closely approximated the values obtained by the standard procedure. This technique should permit making tests on the grain from individual wheat plants leaving a sufficient amount of the wheat for planting. Sedimentation tests may be made in an average time of 5 minutes per sample starting with the original wheat when the prescribed milling procedure (1:5) is used.

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