The Pelshenke Test and Its Value in Estimating Bread-Making Properties of Hard Winter Wheats[1]

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ABSTRACT

The Pelshenke test was evaluated for precision and possible sources of variation. The Pelshenke value of dough made with dry yeast was lower and had a smaller standard deviation than that of dough made with compressed yeast. Variations in hand mixing did not appear to affect the Pelshenke value. Pelshenke values were essentially constant for variations of 12.1–15.0% in protein content of Cloud hard winter wheat grown at one location. However, when the environment varied greatly and inherent quality was kept constant, wheat protein content of 23 location composites varied from 8.8 to 16.2%, and more than 97% of the variability in loaf volume was attributable to protein content alone, whereas 64% of the variability in Pelshenke value was attributable to environmental factors other than protein content. Linear correlations of loaf volume and dough mixing time to Pelshenke value, first when environment was variable and inherent quality was constant, and then when environment was constant and inherent quality was variable, indicated that Pelshenke value is largely a function of the environment and is related to quality and quantity of protein only to a limited (impractical) extent. In addition to protein content, the environment appears to affect the composition and/or quantity of other wheat flour components that affect Pelshenke value to an extent that overshadows the effect of quantity and quality of protein.

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The use of milling and baking performance tests to evaluate lines of wheat at early stages of their breeding is often limited by the small size of the samples and the large number of lines to be tested. The Pelshenke test has been used as a crude measure of flour quality with variable results (Bayfield 1936; Cutler and Worzella 1931, 1933; Pelshenke 1933; Saunders and Humphries 1928; Wilson et al 1933). The test is simple, requires a relatively small sample of grain and no expensive equipment, and can be used daily to evaluate a large number of lines. Swanson (1937, 1939, 1940) and Swanson and Dines (1939) reported that adequate grinding was necessary to obtain reproducible results. They also found that adding yeast, germ, pepsin, cysteine, and particularly, a mixture of pepsin and cysteine to the dough reduced the test time, whereas adding bran, potassium bromate, sugar, and carbon dioxide to the water containing the dough ball increased the test time.

Although the Pelshenke test is used in some breeding programs to identify good bread-making wheat lines, its effectiveness is questionable. This study was designed to investigate factors that affect the test and to determine the effectiveness of Pelshenke values to predict important functional (bread-making) properties.

MATERIALS AND METHODS

Wheat Samples

The effect of protein content on Pelshenke value was studied on samples of Cloud hard winter wheat grown in 1974 at Manhattan, KS. Foliar applications of urea (50–100 lb N/acre) produced wheats with protein contents ranging from 12.1 to 15.0%. Baking results of all samples were normal when considering protein content differences. The control contained 12.1% protein.

The effect of environment on Pelshenke value, loaf volume potential, and mixing time to the peak was studied on 23 location composites. Each contained equal quantities of 25 varieties of hard winter wheat, each grown at the 23 locations in the Southern Great Plains in 1973. Thus, inherent quality was constant. Wheat protein contents varied from 8.8 to 16.2%.

The effect of inherent quality on Pelshenke value, loaf volume potential, and mixing requirement was studied on the following variety composites of hard winter wheat: each of 25 contained equal quantities of a variety harvested at 23 locations in the Southern Great Plains in 1973; each of 13 contained equal quantities of a variety harvested at 13 locations in the Northern Great Plains in 1973; each of 23 contained equal quantities of a variety harvested at 23 locations in the Southern Great Plains in 1974; and each of 22 contained equal quantities of a variety harvested at 12 locations in the Northern Great Plains in 1974. Thus, environment was constant within each group of variety composites.

Protein and moisture were determined by AACC approved methods 46-11 and 44-15A, respectively (AACC 1976). The baking procedure was a straight dough method using optimum mixing, water, and oxidation ($KBrO_3$). The formula was: flour, 100 g; sugar, 6 g; nonfat dry milk, 4.0 g; shortening, 3.0 g; compressed yeast, 2.0 g; salt, 1.5 g; and malt, 0.25 g (barley malt 52 dextrinizing units per gram). Additional details are given by Finney (1945), and Finney and Barmore (1943, 1945a, 1945b).

Sample Preparation

Wheats were ground on a Weber cyclone hammer mill (as modified by Udy), mixed thoroughly, and tested by the Pelshenke method the same day.

Pelshenke Test

Two methods were used to determine the Pelshenke values: the AACC approved method 56-60 (1976) and the methods developed and used at the International Maize and Wheat Improvement Center (CIMMYT). The AACC method requires 4 g of ground meal and 2.25 ml of a yeast suspension that contains 10 g of fresh compressed yeast (usually about 70% moisture) in 100 ml of water. The CIMMYT method requires 3 g of freshly ground meal and 0.057 g of dry yeast (usually about 10% moisture) in 1.8-ml suspension. In other respects, the methods are similar.

Yeast was weighed, slurried with distilled water (25° C), allowed to hydrate for 15 min, and then diluted to volume. Three grams of wheat meal and 1.8 ml of yeast solution were mixed with a spatula in a paper cup until a dough ball was formed. The dough ball was kneaded by hand for about 1 min (or until the surface of the ball was smooth and free of cracks) and placed in a 150-ml beaker containing about 80 ml of distilled water. The beaker and its contents were placed in a fermentation cabinet (National Manufacturing Co.) at 86° F and 85% relative humidity.

The dough ball first sank to the bottom of the beaker but later rose to the top, spread out slowly, and finally started to disintegrate into fragments that fell to the bottom of the beaker. The Pelshenke value was the time, in minutes, between placement of the dough ball

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in water and the start of disintegration. All Pelshenke tests were performed by the same person to minimize operator variation. All values represent averages of at least four determinations.

Mixograph

The 10-g mixograph procedure (Finney and Shogren 1972) was used to study the effect of amount of mixing on the Pelshenke test. A 10-g sample of wheat meal (14% moisture basis) was placed in the mixograph bowl and shaped to form a cavity. After yeast solution and water (total of 6.3 ml) were dispensed into the cavity, the mixogram was recorded.

Fractionation of Dry Yeast

To study the factor in dry yeast responsible for low Pelshenke values, dry yeast (12.8 g) was slurried with distilled water (100 ml), allowed to hydrate for 15 min, then centrifuged at 1,000 × *g* for 15 min (Fig. 1). In addition, the soluble fraction of the dry yeast was separated into two fractions by dialyzing against water: the dialyzate (material diffusing through the dialysis bag), and the dialyzed fraction (material retained in the dialysis bag). The dialyzate was concentrated from 1,000 to 100 ml in a rotary evaporator.

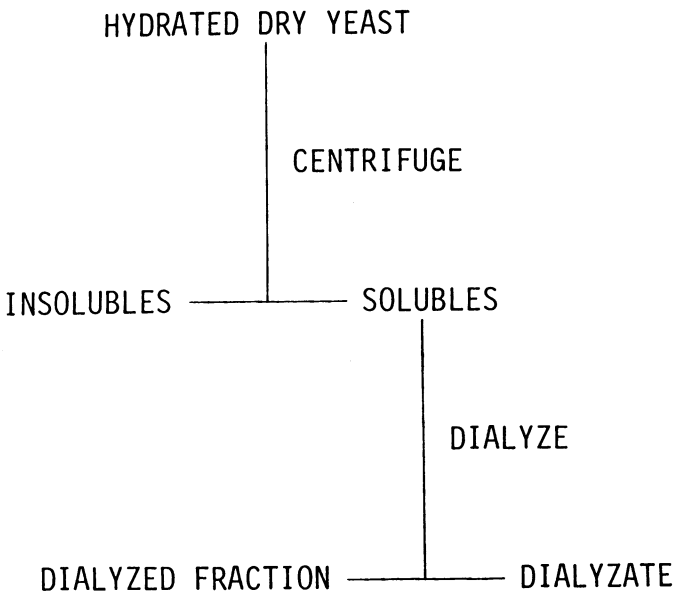

Fig. 1. Scheme for fractionation of dry yeast.

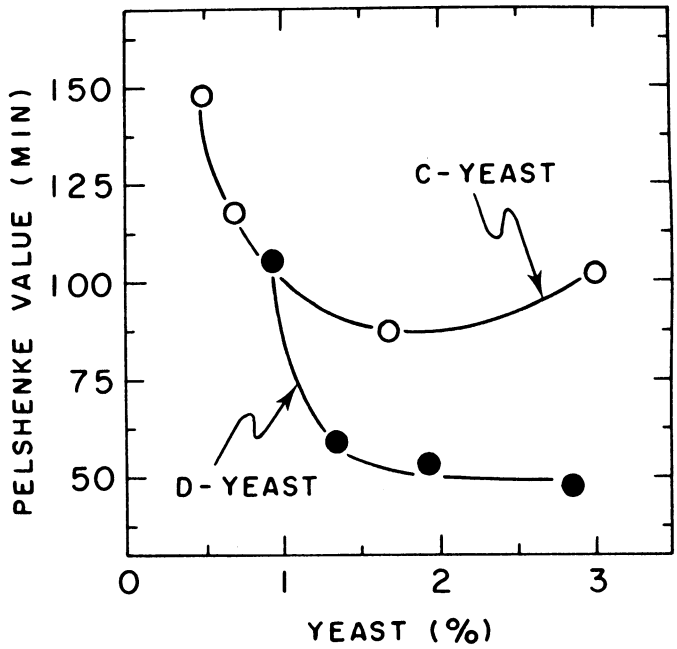

Fig. 2. Effect of concentration of compressed (C) and dry (D) yeasts on Pelshenke values.

RESULTS AND DISCUSSION

Type and Concentration of Yeast

Pelshenke values generally decreased progressively as the concentration of yeast was increased (Fig. 2). However, the Pelshenke values were substantially lower for dry yeast than for compressed yeast. Results were the same with dry yeast from two suppliers. Compressed yeast of the type sold in retail markets and understood to be of the same species as dry yeast (Reed and Peppler 1973) gave much longer Pelshenke times than did either dry yeast or compressed yeast produced for the bakery trade (data not shown).

The precision of Pelshenke values was determined on 3-g replicates from the same meal and 1.68% bakers' compressed yeast (0.0504 g/3 g of meal) in 1.8-ml yeast suspension. The 1.68% yeast corresponds to the minimum value of Fig. 2. Twenty-nine determinations gave a mean of 96 min with a standard deviation of 16 min. A similar study with the same meal but involving 46 determinations with 1.92% dry yeast (0.057 g/3 g of meal) gave a mean value of 54 min and a standard deviation of 3.09 min. The materially decreased mean time, and the accompanying smaller standard deviation suggested that the dry yeast was preferable for the determination of the Pelshenke value.

Fractions of Yeast

Adding 0.45-ml solubles (equal to the quantity of solubles from 0.057 g of dry yeast), 0.0504 g of compressed yeast (1.68% of meal), and enough water to bring the absorption to 60% (1.8 ml/3 g of meal) gave a Pelshenke value of 68 min (Table I). That value was 17 min less than the 85 min of the control sample containing no solubles. Additional increments of the soluble fraction progressively lowered the Pelshenke value. Therefore, apparently the component in dry yeast responsible for the lower Pelshenke values was water-soluble.

When 0.45 ml of the concentrate (equal to the dialyzate from 0.057 g of dry yeast), 0.0504 g of compressed yeast, and enough water to bring the absorption to 60% were added to 3 g of meal, the Pelshenke value (75 min) was 15 min less than the control (90 min) containing no dialyzate (Table I).

The dialyzed fraction did not affect the Pelshenke value when added to meal, compressed yeast, and water. Therefore, the component responsible for the shortened times apparently has a low molecular weight.

Mixograms When Adding Dry or Compressed Yeasts

Ponte et al (1960) has shown that glutathione leached from damaged dry yeast cells during hydration made dough slack and

TABLE I
Effect on Pelshenke Values of Various Water-Soluble Fractions of Dry Yeast[a]

Fraction	Amount of Fraction (ml)	Equivalent Dry Yeast (g)	Pelshenke Value (min)
Solubles	0.0	0.0	85
	0.45	0.057	68
	0.90	0.114	61
	1.35	0.171	60
Dialyzate	0.0	0.0	90
	0.45	0.057	75
	0.90	0.114	66
	1.35	0.171	60

[a]Dough balls were mixed with 3 g of meal, 1.8 ml of total water (60% absorption), 0.0504 g of compressed yeast (1.68% of meal), and various amounts of dry yeast fractions.

more extensible than doughs made with compressed yeast. Glutathione, a tripeptide containing a sulfhydryl moiety, and many other sulfhydryl compounds are known to affect the mixing characteristics of doughs.

When compressed yeast (0.182 g/ 10 g of flour) was added to the standard flour, mixing time to the point of minimum mobility was reduced from 3.25 to 2.75 min (Fig. 3). Dry yeast (0.208 g/ 10 g of flour) reduced mixing time of the standard flour from 3.25 to 1.75 min. Adding glutathione (30 ppm) to the standard flour reduced mixing time from 3.25 to 2.125 min, a decrease somewhat less than that when dry yeast was added. Potassium iodate (30 ppm) added with dry yeast (0.208 g/ 10 g of flour) to the standard flour increased the mixing time from 1.75 to 2.5 min. Oxidants such as potassium iodate are known to oxidize sulfhydryl groups to disulfide bonds and to not reduce mixing time (Weak et al 1977).

Pelshenke values of the standard meal averaged 54 min for the dry yeast procedure. Adding 25 ppm of glutathione reduced the value to 49 min; increasing the level of glutathione to 50 ppm did not reduce the time further. Adding 25 ppm KIO_3 increased the Pelshenke time to 86 min. Adding 50 ppm increased the time to more than 150 min. Thus, it appears that the Pelshenke values for dry yeast are lower than those for compressed yeast, at least in part, because glutathione probably was leached from the dry yeast cells.

Varying Amounts of Mixing

The mixogram of the standard meal peaked at 2.25 min. Standard meal doughs made with 10 g of meal and dry yeast were mixed for various periods of time in the mixograph. After mixing, dough balls weighing 4.6 g (equal to 3 g of dry meal plus yeast and water) were scaled from the dough, and their Pelshenke values determined (Fig. 4). Dough mixed for 0.5 or 1 min had Pelshenke values equal to those of hand-mixed doughs. Thus, small mixing variations, comparable to those expected from hand mixing, had essentially no effect on Pelshenke value. When doughs were mixed for longer than 1 min, Pelshenke value increased with increasing mixing time.

Varying Protein Content at Manhattan Within a Variety

Pelshenke values (with dry yeast) for 15 samples of Cloud hard winter wheat were essentially equal (Table II), even though protein content varied from 12.1 to 15.0% at Manhattan, KS. For example, the average Pelshenke deviation of the first five samples (12.16% protein) from the mean of 15 samples was only −2.4 min, whereas the average deviation of the last five samples (14.54% protein) from the 15-sample mean was only +1.6 min. Pelshenke values for compressed yeast (data not given) were higher and more variable than those for dry yeast, but they still were not a function of protein content.

Variable Environment and Constant Inherent Quality

Loaf volumes of flours milled from the 23 station composites (each made up of the 25 hard winter wheat varieties harvested in the Southern Great Plains in 1973) were very highly significantly correlated (r = 0.986) with wheat protein content (Fig. 5, top). Even though the 23 stations or locations represented a wide range of environments, protein content accounted for more than 97% of the

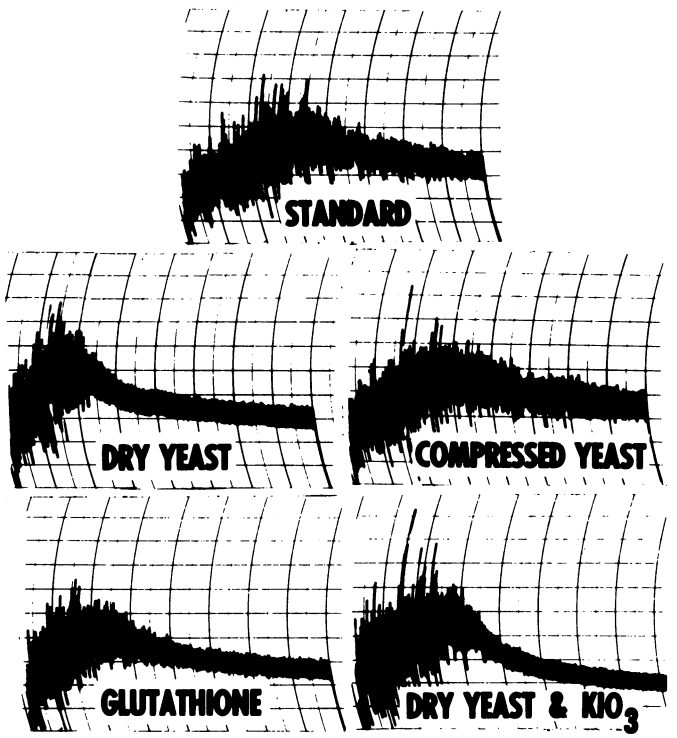

Fig. 3. Effects of dry yeast (0.208 g), compressed yeast (0.182 g), glutathione (30 ppm), and dry yeast plus potassium iodate (30 ppm) on mixogram mixing time to the peak (point of minimum mobility).

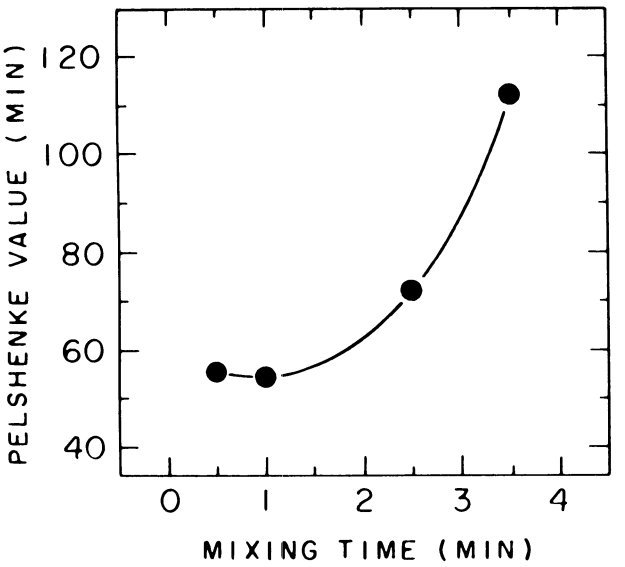

Fig. 4. Effect of various amounts of mechanical mixing (mixograph) on Pelshenke value.

TABLE II
Protein Content and Pelshenke Value (Dry Yeast Method) of 15 Samples of Cloud Hard Winter Wheat That Varied in Protein Content from 12.1 to 15.0% When Grown at Manhattan, KS at Different Nitrogen Levels

	Pelshenke Value	
Wheat Protein (%)	As Received (min)	Deviation From Mean (min)
12.1	51	−6.8
12.1	55	−2.8
12.2	55	−2.8
12.2	56	−1.8
12.2	60	+2.2
12.16 av. first 5	55.4	−2.4
13.4	63	+5.2
13.5	55	−2.8
13.5	60	+2.2
13.7	55	−2.8
13.9	60	+2.2
13.6 av. second 5	58.6	+0.8
14.1	55	−2.8
14.2	58	+0.2
14.6	65	+7.2
14.8	63	+5.2
15.0	56	−1.8
14.54 av. third 5	59.4	+1.6
Mean 13.43	57.8	0.0

variability in loaf volume.

Although Pelshenke value (with dry yeast) was significantly correlated (r = 0.60) with wheat protein content (Fig. 5, bottom), only 36% of the variability in Pelshenke value was accounted for by protein content. Of course, the large variation in wheat protein content was a function of the different environments. When the environment was constant (Manhattan, KS, Table II), protein content had essentially no effect on Pelshenke value. Thus, Pelshenke value appears to be primarily a function of the growing environment.

Loaf volume was significantly correlated with Pelshenke value (r = 0.57, Fig. 6, top); but only about 32% of the variations in loaf volume was accounted for by variations in Pelshenke value, results anticipated from the data in Fig. 5.

Corrected mixing time was very highly significantly correlated with Pelshenke value (r = 0.81, Fig. 6, bottom). When producing a continuous phase of protein during mixing to the point of minimum mobility in breadmaking, protein content becomes increasingly limiting as it decreases below about 12%. Thus, when flour protein content was below 12%, mixing time was decreased about 12% for each 1 percentage point of protein below 12% (Finney and Shogren 1972). However, the variations in mixing time are functions of the environment for a constant inherent quality level (each of the 23 location samples was a composite of the same 25 varieties of wheat). Thus, variations in mixing time within an inherent quality level appear to reflect the effects of the different environments to about the same extent as the variations in Pelshenke value.

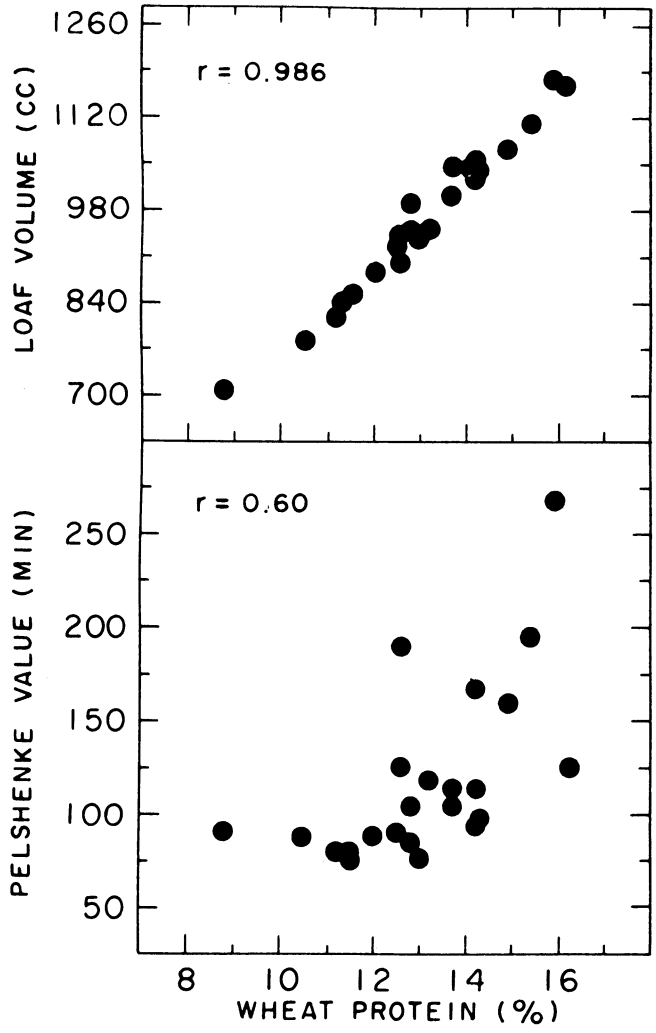

Fig. 5. Relation of loaf volume or Pelshenke value to protein content of 23 location composites of hard winter wheat varieties harvested in the Southern Great Plains of the United States in 1973. Each location composite contained equal amounts of the same 25 varieties.

Constant Environment and Variable Inherent Quality

The effect of environment was eliminated by compositing the locations (environments) within a variety. A variety then represents a level of quality that is defined in terms of functional properties such as loaf volume or mixing time to the peak or point of minimum mobility. Loaf volume of flours milled from 83 variety composites (1973 and 1974 crops) was significantly correlated with Pelshenke value (r = 0.34, Fig. 7, top), but the relationship was of no practical value for predicting loaf volume from Pelshenke value (with dry yeast). Similar significant correlation coefficients for 1973 only and 1974 only were 0.28 and 0.37, respectively.

Dough mixing time to the peak of the 83 flours was very highly significantly correlated with Pelshenke value (r = 0.61, Fig. 7, bottom). Significant correlation coefficients of 0.65 for 1973 only and 0.68 for 1974 only were somewhat higher than 0.61 because the regression line for 1974 was materially above that for 1973. The

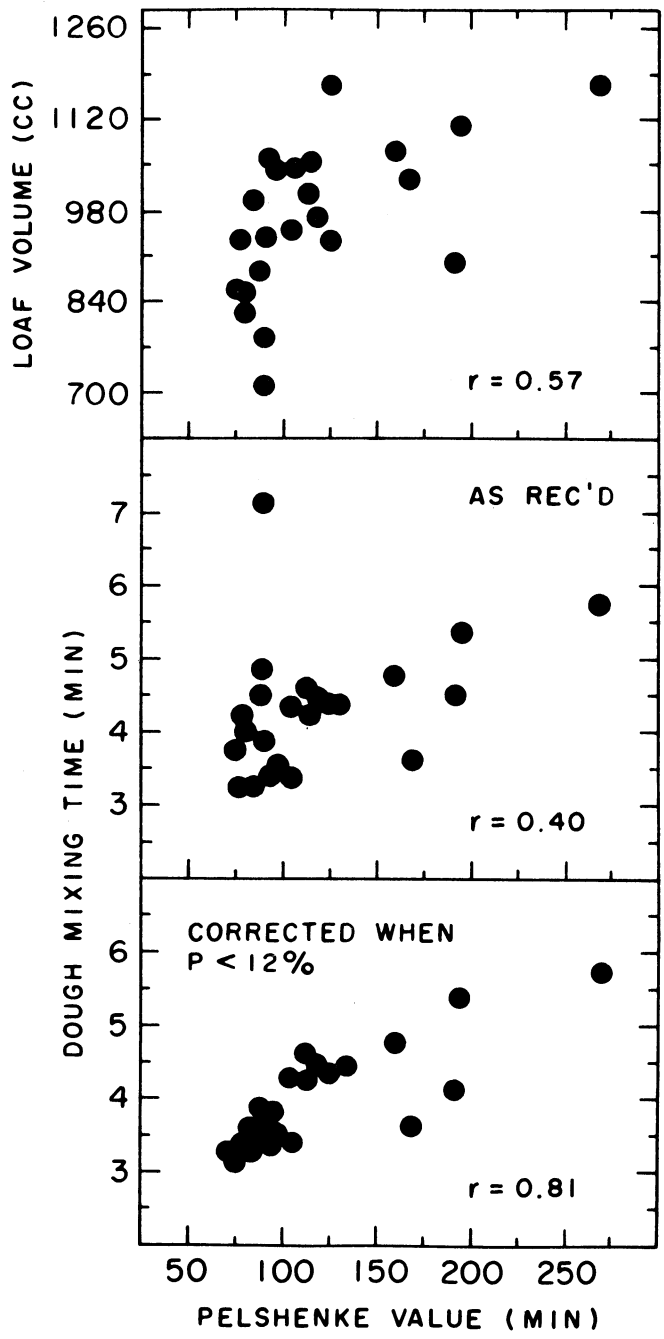

Fig. 6. Relation of loaf volume or bread dough mixing time to Pelshenke value of 23 location composites of hard winter wheat varieties harvested in the Southern Great Plains of the United States in 1973. Each location composite contained equal amounts of the same 25 varieties.

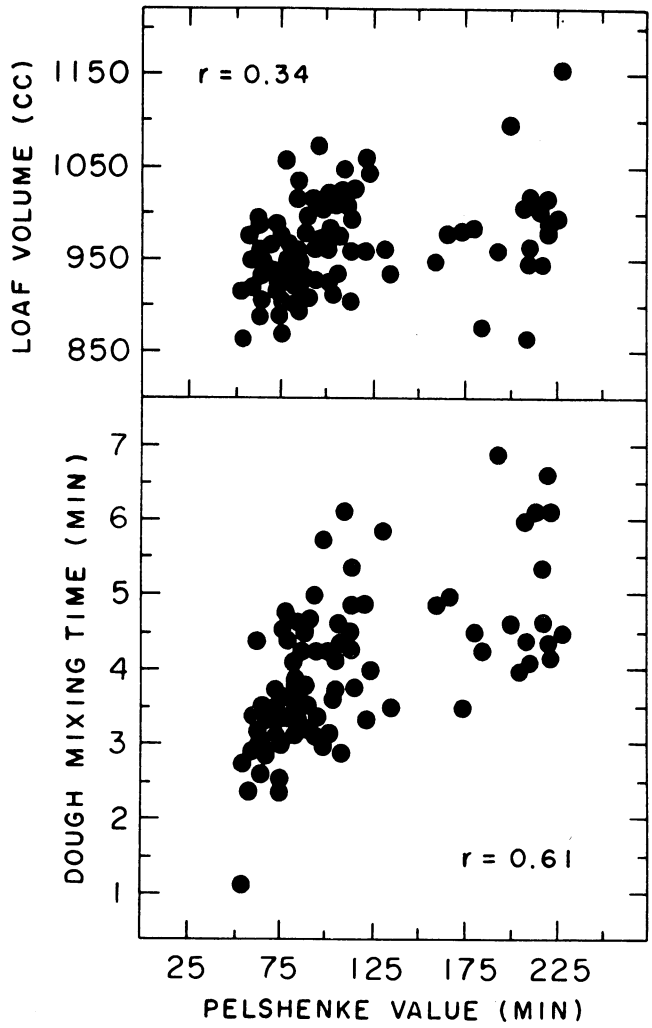

Fig. 7. Relation of loaf volume or bread dough mixing time to Pelshenke value of 83 variety composites of hard winter wheat varieties harvested at different locations in the Southern and Northern Great Plains of the United States in 1973 and 1974.

relationship represented by r = 0.61 was of little practical value for predicting mixing time because Pelshenke value accounted for only 37% of the variability in mixing time between varieties. When quality (variety) was constant (Fig. 6, bottom), Pelshenke value accounted for 66% (nearly twice 37%) of the mixing time variability attributable to environment.

Thus, the Pelshenke value appears to be largely a function of the environment and is related to quality and quantity of protein only to a very limited (impractical) extent. In addition to protein content, the environment appears to affect the composition and/or quantity of other wheat flour components that affect Pelshenke value to an extent that overshadows the effect of quantity and quality of protein.

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