Factors Contributing to Baking Quality Differences in Hard Red Spring Wheat. II. Bases for Different Mixing Properties[1]

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ABSTRACT

The bases for different mixing properties of two hard red spring wheats (Olaf and F01277) were investigated, utilizing fractionation and reconstitution techniques and a correlation study. The stronger mixograph curve characteristics of Olaf resided primarily in the gluten fraction. The higher residue protein content of this variety appeared to explain most of the gluten effect. The residue protein did not, however, appear to affect the curve height at optimum development time and had a relatively small effect on curve height after 8 min of mixing. As could be expected, total protein content related negatively to peak time and positively to peak height (at a constant water absorption). Total pentosan content appeared to have a small positive effect on peak height and height after 8 min. The albumin protein content affected peak time and curve width positively. However, the albumin proteins appear to sometimes have a negative effect on peak time, depending on the manner in which they interact with entities in the gluten and tailings fractions. Gliadin content showed a positive association with mixograph peak area among 21 progeny lines. No evidence could be found of a significant effect on mixing behavior by proteolytic enzymes (in sound flours).

The first event in the mixing process is hydration, a slow process that is accelerated by the mixing action. As water penetrates the flour particles, the mixing action promotes removal of hydrated layers. The hydrated mass loses some of its excess free water to the remaining unhydrated flour particles. This process is repeated until all of the particles are hydrated and the free water in the hydrated mass has dropped to a level that produces a dough that can be altered by mixing. The rheological properties that develop upon continued mixing are peculiar to the variety and growing conditions (Hoseney and Finney 1974). Variability in mixing times among samples has been shown to reside primarily in the protein fractions and to be related to total protein, water solubles, glutenin, residue protein, and the gliadin/glutenin ratio (Bietz et al 1973, Hoseney and Finney 1971, Orth and Bushuk 1972).

A possible role for proteolytic enzymes in rheology has been suggested (Hanford 1967, McDonald and Chen 1964), but confirmation of such a role has not been found (Ewart 1977).

Although pentosan additions to flour seem to result in effects on mixing characteristics, the literature indicates that effects by the levels normally present in flour are small or absent (Ali 1978).

The aim of this study was to investigate biochemical factors contributing to varying mixograph characteristics among wheat varieties. For this purpose, the parents and progeny of a cross between the hard red spring wheats Olaf and F01277 were utilized in reconstitution and correlation studies. Olaf is a cultivar with relatively strong mixing characterisitics as compared to those of F01277.

MATERIALS AND METHODS

Samples

Flour of the hard red spring wheat variety Olaf and of a breeding line (F01277) was obtained by Buhler-milling of a composite wheat sample. The composite was made up of grain harvested from replicated plots grown at Casselton and Fargo, ND, in 1977. This flour was used in reconstitution studies.

For correlation studies, samples of 21 F_2-derived F_3 lines (Fargo crop) from a cross between the two wheats were milled on a Quadrumat Junior laboratory mill.

The line F01277 has the following pedigree: Ciano 67/3/Agent/Timopheevi derivation//Wisconsin 261/4/ND 259/Conley/3/Conley/ND 122//Justin.

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Mixograph

In both the reconstitution studies and the correlation studies, a 25-g fixed water absorption (60% based on dry solids) and a spring setting of 10 was used. Mixogram measurements were made for mixing time, peak height, peak area, curve area, breakdown, width, and height after 8 min of mixing or at a point 15 cm from the origin. These dimensions are illustrated in Fig. 1

Pentosan Contents

Total pentosan contents were estimated according to the method of Dische and Borenfreund as modified by Cracknell and Moye[3] and further modified by MacArthur and D'Appolonia (1977).

Damaged Starch Content

The procedure of Williams and Fegol (1969) was used. Values are expressed as absorbance times 10.

Protein Content

The AACC macro-Kjeldahl procedure was used to measure protein.

Proteolytic Activity

Two methods were used to determine protease activity: 1) the Ayre-Anderson method as described by Hanford (1967), in which the amount of peptides liberated during the incubation period was measured by a Lowry procedure (Bailey 1962); and 2) the azocasein method described by Kruger (1971), without modification.

Flour Protein Fractions

The levels of the various protein fractions were determined using the modified Osborne procedure described by Chen and Bushuk (1970). Residue protein contents were also determined using the rapid procedure described by Orth and O'Brien (1976).

Flour Fractionation

Flour was fractionated into gluten, starch, tailings, and water solubles. In some cases the water-soluble fraction was subfractionated to yield albumin, globulin, and dialysate subfractions. These techniques have been described (Marais and D'Appolonia 1981).

Isolation of Crude Water-Soluble and Insoluble Pentosans

A modification of the methodology described by Kim and D'Appolonia (1976) was used (Fig. 2).

[3]R. L. Cracknell and C. J. Moye. 1970. A colourimetric method for the determination of pentosans in cereal products. 20th Annual Conference, Royal Australian Chemical Institution.

Kernel Hardness

The pearling index described by McCluggage (1943) was used to measure kernel hardness.

Flour Reconstitution Studies

Flour reconstitution studies were done using flour fractions obtained from the two parental sources.

Experiment 1. To identify flour components housing the causes for the different mixing characteristics of the two wheats and also to detect possible interactions of such components, the isolated gluten, starch, tailings, and unfractionated water solubles from each source were recombined in all possible combinations of a 2^4-factorial experiment (using the Olaf fraction yields).

In addition, two one-fraction-at-a-time interchanges involving the gluten fraction were made, using proportions that resulted in the same total protein content as in the uninterchanged flour.

In each case, 30 g of flour were prepared and thoroughly blended. Mixograms were made in triplicate using a 10-g mixograph. The characteristics of the original flours were regained best if the mixograph was stopped after 15 sec and the sides of the mixing bowl scraped. This, however, had an effect on some mixograph characteristics.

Experiment 2. To further study the water-solubles fraction, isolated subfractions (albumin, globulin, and dialysate obtained by a dialysis technique) from the two water-solubles sources were recombined in all combinations of a 2^3-factorial experiment (with two replications). Interchanges were made using each fraction's own "as is" yield. A base flour consisting of Olaf gluten, starch, and tailings (made up to the Olaf ratios) was used to prepare the remainder of each combination. Recombined flours were subsequently ground to a uniform mixture using a mortar and pestle. Ten-grams mixograms were obtained using these flours.

Experiment 3. To study the role of water-soluble and insoluble pentosans, the following experiment was conducted. Crude water-soluble and tailings pentosans were extracted. These fractions were added back to base flours in amounts equal to once, twice, and three times the proportions isolated. For the water-soluble pentosan study, the base system consisted of F01277 starch, gluten, and tailings. In the case of the tailings pentosan study, the base system consisted of F01277 gluten, starch, water solubles, and starch-rich tailings. All fractions were recombined according to the Olaf fraction yields. A single 10-g mixogram was obtained for each combination.

Experiment 4. To investigate the possibility of an endoprotease affecting mixing characteristics, the following experiment was conducted. Using Olaf starch, tailings, and water solubles in the Olaf ratios, a base flour was prepared. To this base flour, gluten from Olaf or F01277 was added after being treated in one of several ways. The variations were: 1) unaltered dry gluten (control), 2) gluten wetted with 110% distilled water and placed in a fermentation cabinet for 2 hr at 30° C, 3) gluten given the same treatment except for a longer rest (4 hr), 4) powdered gluten dispersed in McIlvaines buffer, pH = 6.0, and mildly shaken for 2 hr at 40° C (conditions of the azocasein method).

These fractions were subsequently freeze-dried, ground with a mortar and pestle, and added to the base flour. Ten-gram mixograms using these materials were made.

Correlation Study

To investigate the unexplained effects further, flour from the two parental lines, F01277 and Olaf, and 21 F_3 progeny lines (Quadrumat milled) were fractionated according to the modified Osborne procedure. The total protein recovery ranged from 88.8 to 96.8%. In addition, pentosan contents, residue protein contents (Orth and O'Brien procedure), and protease determinations (modified Ayre-Anderson procedure) were made on all samples. For each line, a 25-g mixogram was obtained.

Statistical Analyses

The factorial experiments were analyzed assuming a fixed model (Steel and Torrie 1960).

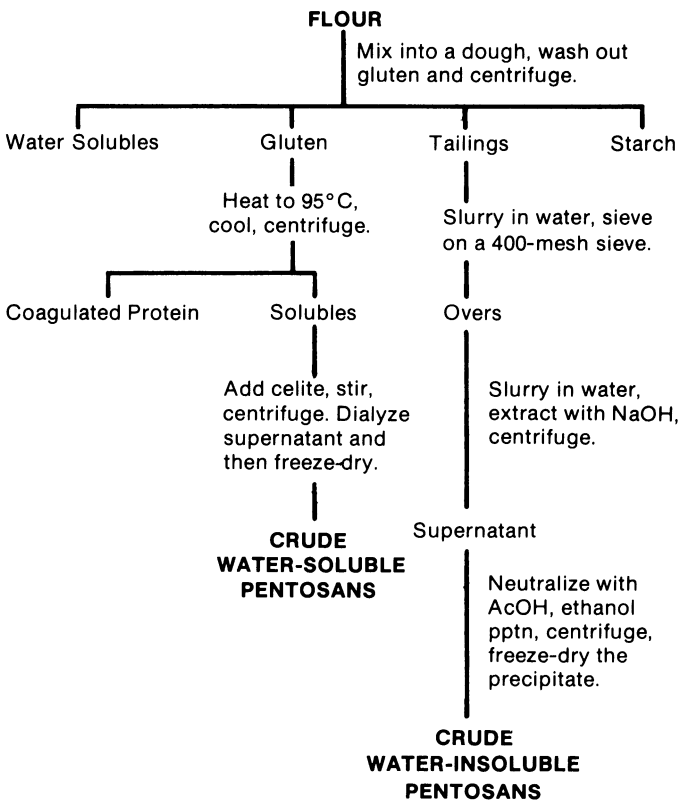

Fig. 2. Isolation of pentosans by a modification of the method of Kim and D'Appolonia (1976).

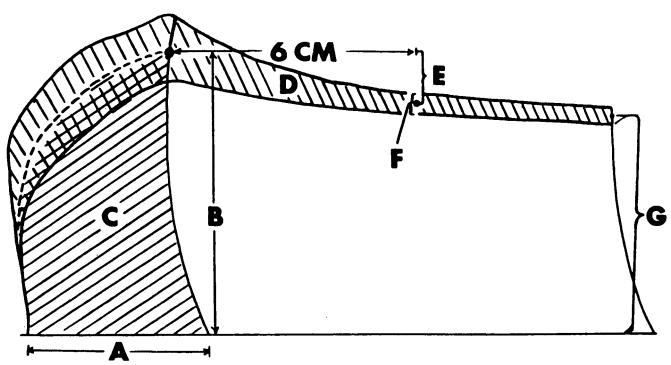

Fig. 1. Measurements obtained from mixograms: **A,** mixing time (cm); **B,** peak height (mm); **C,** peak area (cm^2); **D,** curve area (cm^2); **E,** breakdown (cm); **F,** width (cm); **G,** height after 8 min or at point 15 cm from origin (mm).

TABLE I
Fractionation Data[a] on Wheat Varieties Olaf and F01277

	Yield (percent of) total flour)		Contents (%)			
			Protein		Pentosan	
Fraction	Olaf	F01277	Olaf	F01277	Olaf	F01277
Gluten	0.22	0.26	60.4	55.0	···	···
Starch	0.42	0.36	0.3	0.3	···	···
Tailings	0.30	0.33	0.7	0.7	2.1	2.5
Water solubles	0.050	0.049	18.9	19.0	15.7	9.6
Albumin[b]	0.019	0.016	36.5	43.0	···	···
Globulin[b]	0.002	0.002	42.5	45.5	···	···
Dialyzate[b]	0.029	0.031	7.7	8.3	···	···
Unfractionated flour	···	···	14.4	15.6	1.8	1.2

[a] 14% mb, except where noted.
[b] As is basis.

RESULTS AND DISCUSSION

Reconstitution Studies

Total Flour. Data obtained on the fractionation of the two parental flours into gluten, starch, tailings and water solubles (Experiment 1) are summarized in Table I. A comparison of mixograph characteristics of original and reconstituted flours is given in Table II. The major deviations were observed for characteristics influenced by the initial hydration characteristics (mixing time, curve area, and peak area). The reconstitution procedure markedly changed the hydration phase of the curves (Fig. 3).

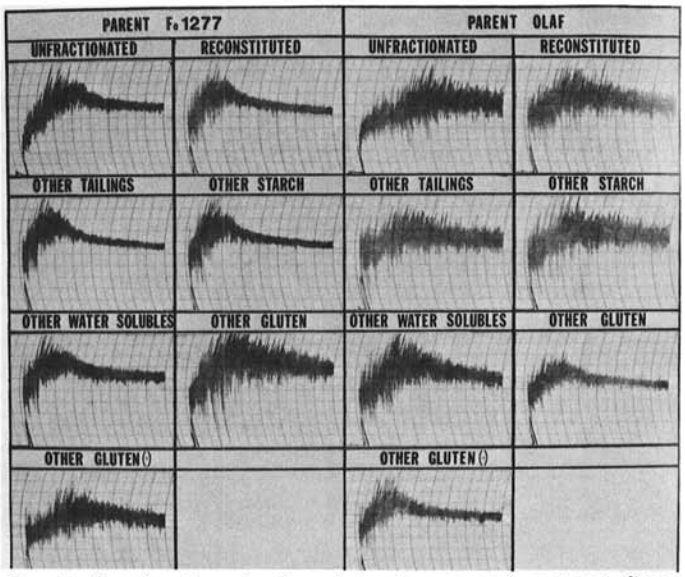

Fig. 3. One-fraction-at-a-time interchanges and parental flour reconstitution involving Olaf and F01277 fractions.

The results of an analysis of variance executed on the factorial data are presented in Table III, and representative mixograms of the combinations involved are shown in Fig. 3.

Gluten and water solubles had a significant effect on all characteristics measured, the gluten effect being quite pronounced. Results on gluten fraction interchanges to the same protein contents confirmed that these differences were largely due to protein quality effects. The tailings fraction caused significant differences in the case of mixing time, peak height, and curve area. Several interaction effects were significant as well. The averages obtained for the significant main effects are given in Table IV. These averages indicate that the Olaf gluten and water-soluble fractions result in stronger mixing characteristics. The Olaf tailings fraction reduced mixing time and curve area but increased peak height. The three fractions that affected mixing properties in the two wheats were subsequently investigated further.

Water-Soluble Subfractions. To further investigate the bases for observed water-solubles effects, Experiment 2 was conducted.

Data pertinent to the fractionation of water solubles into albumin-rich, globulin-rich, and dialysate subfractions are summarized in Table I.

The analysis of variance on a factorial experiment involving interchanges of these fractions is presented in Table V.

These data indicated that the albumin-rich fraction interchanges caused significant effects in the case of mixing time, peak height,

TABLE II
Effect of Reconstitution (Experiment 1) on Mixing Properties

Characteristic	Olaf		F01277		Least Significant Difference ($P = 0.01$)
	Original	Reconstituted	Original	Reconstituted	
Mixing time (cm)	8.70	5.00	6.00	3.70	0.67
Peak height (mm)	76.80	82.50	83.30	86.70	5.70
Width (cm)	2.05	2.02	0.87	0.68	0.22
Breakdown (cm)	0.55	0.88	1.45	1.78	0.44
Curve area (cm^2)	40.90	37.60	27.10	21.00	3.42
Peak area (cm^2)	54.40	31.90	36.90	24.90	4.81
Height after 8 min (mm)	70.80	69.70	67.00	63.70	3.21

TABLE III
Analysis of Variance of Factorial Experiment 1[a]

Source of Variance	Degrees of Freedom	Mean Square						
		Mixing Time	Peak Height	Width	Breakdown	Curve Area	Peak Area	Height (8 min)
Treatments	15	1.39[b]	36.07[b]	1.07[b]	0.25[b]	312.54[b]	84.63[b]	109.77[b]
S	1	0.16	4.08	0.00	0.00	2.80	9.19	0.19
G	1	18.07[b]	391.02[b]	15.13[b]	2.93[b]	4,570.80[b]	1,045.33[b]	1,323.00[b]
S × G	1	0.04	4.69	0.00	0.03	4.56	1.02	0.19
T	1	0.62[c]	28.52[c]	0.01	0.14	11.80[c]	6.31	0.52
S × T	1	0.00	4.69	0.00	0.02	0.37	0.75	0.08
G × T	1	0.00	8.33	0.00	0.00	5.74	9.54	4.69
S × G × T	1	0.45[c]	4.08	0.00	0.00	0.00	21.33[c]	0.33
W	1	0.47[c]	33.33[c]	0.79[b]	0.49[b]	32.01[b]	128.05[b]	270.75[b]
S × W	1	0.10	4.08	0.00	0.00	10.45[c]	4.44	1.69
G × W	1	0.06	25.52	0.02	0.07	42.56[b]	11.21	18.75[b]
S × G × W	1	0.08	0.52	0.00	0.01	3.63	0.24	0.52
T × W	1	0.28	25.52	0.03	0.02	0.52	8.84	17.52[b]
S × T × W	1	0.00	2.52	0.00	0.00	0.61	0.16	5.33
G × T × W	1	0.43[c]	4.08	0.01	0.00	2.17	20.02[c]	1.69
S × G × T × W	1	0.05	0.00	0.00	0.01	0.01	3.00	1.33
Error	32	0.09	6.49	0.01	0.04	2.34	4.63	2.06
Total	47							

[a] S = starch, G = gluten, T = tailings, W = water solubles.
[b] $P = 0.01$.
[c] $P = 0.05$.

width, and height after 8 min. The only other effect that was significant was caused by the dialysate on height after 8 min. Averages obtained for the different fractions are presented in Table VI. The Olaf albumin fraction resulted in higher values for peak height, width, and height after 8 min and gave a lower average for mixing time. The effect on mixing time appears to be opposite to the total water solubles effect. However, this effect can be explained in terms of the significant interactions of Table III, which indicate a significant gluten × tailings × water solubles interaction for mixing time. The averages obtained in this experiment suggest that Olaf water solubles cause a negative effect on mixing time in the presence of Olaf gluten and tailings. For all other combinations of gluten and tailings, the Olaf water solubles effect is positive. Thus the albumin-rich fraction is implicated in this interaction.

Since the albumin-rich fraction also contains most of the water-soluble pentosans, a further study was made to determine the significance of the pentosans in accounting for the behavior of the albumin-rich fraction. The water-insoluble pentosans were also studied in an attempt to account for some of the significant tailings effects reported earlier.

Pentosan Additions. Crude water-soluble and insoluble pentosans were extracted from both F01277 and Olaf and added back to base flours in varying amounts (Experiment 3). The proportions in which the different fractions were obtained and their pentosan contents are summarized in Table VII. The effects on the different mixograph characteristics of increasing pentosan additions are summarized in Table VIII.

Increasing the pentosan levels seems to affect only peak height and height after 8 min, a positive effect (Table VIII). In Experiment 1, the difference in amount of pentosan contributed to factorial combinations by the two tailings sources was rather small (Table I). Furthermore, the Olaf tailings contributed less pentosan to such combinations yet caused a higher peak height. We therefore concluded that the small pentosan difference does not account for any of the observed effects in the tailings. The possibility of a damaged starch effect is also remote because Olaf and F01277 had very similar pearling indexes (63.3 and 63.0, respectively) and similar levels of damaged starch in their flours (4.52 and 4.43, respectively). Evidently some other factor(s) are involved, the detection of which might prove difficult.

An estimated pentosan difference of 0.31% was found between the water-solubles interchanges of the factorial experiment involving the four basic fractions (Table VII). We concluded that such a difference can account, to a great extent, for the observed differences in mixograph peak height and height after 8 min. The differential mixing times and curve widths associated with the albumin-rich fraction appear to require the presence of the protein in this fraction.

TABLE IV
Averages for the Significant Main Effects of Table III

	Gluten from		Water Solubles from		Tailings from	
Characteristic	**Olaf**	**F01277**	**Olaf**	**F01277**	**Olaf**	**F01277**
Mixing time (cm)	5.30	4.07	4.79	4.59	4.57	4.80
Peak height (mm)	80.44	74.73	78.42	76.75	78.35	76.81
Width (cm)	1.85	0.72	1.41	1.16	···	···
Breakdown (cm)	0.82	1.32	0.97	1.17	···	···
Curve area (cm^2)	39.53	20.02	30.59	28.96	29.28	30.27
Peak area (cm^2)	33.12	23.78	30.08	26.82	···	···
Height after 8 min (mm)	68.21	57.71	65.33	60.58	···	···

Correlation Study

Fractionation, mixograph studies, and analysis were conducted on F01277, Olaf, and 21 F_3 progeny lines.

The range obtained for each characteristic is indicated in Table IX.

The stepwise regression procedure was subsequently used to derive some best-fitting models for the prediction of mixograph characteristics. Only variables contributing significantly to the regression sum of squares at the 5% level were retained. The results are given in Table X.

These results indicate that residue protein as measured by the Orth and O'Brien procedure can explain a fair amount of the variability in mixing time, width, peak area, and height after 15 cm. Total protein content was also important for mixing time, peak height, and height (15 cm), whereas gliadin and pentosan contents affected peak area and height (15 cm), respectively. Peak height seems to be unaffected by the amount of residue protein. This conclusion can also be drawn from the reconstitution study involving the four basic flour fractions (a part of Experiment 1). In this case, the gluten interchanges were made in two ways: 1) using a fixed ratio, and 2) in proportions that resulted in the same gluten protein content. The data of Table XI are drawn from this study.

The gluten factor responsible for peak height fluctuations appears to be the gluten protein content. Little evidence of gluten quality effect can be found. For 8-min height, after consideration is given to the protein content, a higher value is still associated with the Olaf gluten. But evidently some factors remain undetected, especially in the case of peak height and breakdown.

Protease Study

Several considerations prompted a further investigation (Experiment 4) of the role of proteolytic enzymes in determining the mixing characteristics of the two wheats. The possibility of such an effect could not be excluded on the basis of the preceding data because 1) the absorbance values suggested that the differences in protease content among lines were rather small, 2) as Kruger and Preston (1976) pointed out, a determination based on one substrate and pH optimum does not seem to measure all of the different proteases, and 3) endopeptidases can be expected to have a larger effect on mixing behavior than do exopeptidases (Hanford 1967). The Ayre-Anderson method might be measuring primarily exopeptidase activity (Hanford 1967, Kruger and Preston 1976).

TABLE V
Analysis of Variance of Factorial Experiment 2 Involving Water-Solubles Subfractions[a]

		Mean Square						
Source	**Degrees of Freedom**	**Mixing Time**	**Peak Height**	**Width**	**Breakdown**	**Curve Area**	**Peak Area**	**Height (8 min)**
Treatments	7	0.26	7.59	0.02	0.01	5.53	6.02	5.41[b]
A	1	1.24[b]	23.77[b]	0.08[b]	0.01	0.77	28.09	19.14[c]
G	1	0.29	11.39	0.00	0.02	2.48	7.29	3.52
A × G	1	0.11	1.27	0.01	0.00	6.13	0.01	0.77
D	1	0.01	6.89	0.02	0.01	7.43	0.04	9.77[b]
A × D	1	0.03	0.02	0.04	0.00	1.76	5.29	2.64
G × D	1	0.17	9.77	0.01	0.05	10.73	1.44	0.14
A × G × D	1	0.00	0.02	0.01	0.01	9.46	0.01	1.89
Error	8	0.18	3.86	0.01	0.01	3.52	7.03	1.36

[a] A = albumin, G = globulin, D = dialysate.
[b] $P = 0.05$.
[c] $P = 0.01$.

Not only proteases but also other types of enzymes such as reductases may cause intramolecular breakages (Hanford 1967).

Considering the fraction interchanges of Fig. 1, if enzymatic degradation of gluten proteins plays a significant role in determining the characteristic mixing properties of a specific genotype, then the components responsible for such degradation must be housed in the gluten (because interchanges of the other fraction produced only minor variations). McDonald and Chen (1964) did, in fact, show that not all proteolytic activity was extractable.

Using the azocasein method, which Kruger and Preston (1976) suggested was a better indicator of endoproteolytic activity, no indication of enzyme activity could be found in either of the two gluten sources. In order to verify these results, the following experiment was conducted. Using Olaf starch, tailings, and water solubles in the Olaf ratios, a base flour was prepared. Gluten from Olaf or F01277 that was treated in several ways was added to this base flour.

Mixograms reflecting the effects of the different treatments are shown in Fig. 4. A starch-gluten mixture (control) for each gluten is also included.

Figure 4 shows no indication of the presence of a differential gluten weakening activity strong enough to account for the

TABLE VI
Averages for the Various Effects and Characteristics of Water-Solubles Factorial Experiment

	Albumin		Globulin		Dialysate	
Characteristic	**Olaf**	**F01277**	**Olaf**	**F01277**	**Olaf**	**F01277**
Mixing time (cm)	6.41	6.97	6.56	6.83	6.66	6.72
Peak height (mm)	80.44	78.00	80.06	78.38	79.88	78.56
Width (cm)	1.90	1.76	1.82	1.84	1.86	1.79
Breakdown (cm)	0.68	0.62	0.68	0.61	0.68	0.62
Curve area (cm^2)	42.08	41.64	42.25	41.46	42.54	41.18
Peak area (cm^2)	40.90	43.55	41.55	42.90	42.28	42.18
Height after 8 min (mm)	71.63	69.44	71.00	70.06	71.31	69.75

TABLE VII
Data on Isolation of Crude Water-Soluble and Tailings Pentosans (Experiment 3)

	Proportion	Content (%)	
Fraction	**Extracted**	**Pentosan[a]**	**Protein[a]**
Crude water-soluble pentosans			
Olaf	0.009	63.81	3.2
F01277	0.006	51.63	2.6
Water-solubles of base flour	...	0.92	...
Crude tailings pentosans			
Olaf	0.005	55.28	7.3
F01277	0.007	50.91	7.5
Tailings of base flour	...	.54	...

[a]As is.

TABLE VIII
Mixograph Data Obtained Upon Addition of Increasing Levels of Crude Water-Soluble and Insoluble Pentosans to Reconstituted Basic Flours (Experiment 3)

		Amount of Pentosans Added			
Characteristic	**Crude Pentosan Source**	**Parent**	**P[a]**	**2P**	**3P**
Mixing time (cm)	Water solubles	Olaf	5.65	4.45	5.55
		F01277	4.70	4.75	5.60
	Tailings	Olaf	4.25	4.50	4.70
		F01277	5.05	4.80	4.30
Peak height (mm)	Water solubles	Olaf	74.0	78.0	82.0
		F01277	74.0	74.0	77.0
	Tailings	Olaf	68.0	71.5	75.0
		F01277	74.0	74.5	75.0
Width (cm)	Water solubles	Olaf	1.10	1.30	1.45
		F01277	1.50	1.30	1.00
	Tailings	Olaf	0.65	0.60	0.70
		F01277	0.55	0.65	0.65
Breakdown (cm)	Water solubles	Olaf	0.85	0.95	1.15
		F01277	0.70	0.85	1.15
	Tailings	Olaf	1.40	1.65	1.70
		F01277	1.90	1.80	1.60
Curve area (cm^2)	Water solubles	Olaf	27.8	28.8	31.8
		F01277	29.0	27.6	25.5
	Tailings	Olaf	18.3	16.6	20.3
		F01277	17.8	19.7	18.3
Peak area (cm^2)	Water solubles	Olaf	23.3	27.7	39.0
		F01277	29.4	29.1	36.4
	Tailings	Olaf	21.9	24.5	28.0
		F01277	22.5	27.3	22.9
Height after 8 min (mm)	Water solubles	Olaf	62.0	64.5	65.5
		F01277	62.5	62.5	63.0
	Tailings	Olaf	50.5	51.0	54.5
		F01277	51.0	52.5	55.0

[a]Proportion of isolated crude pentosans.

TABLE IX
Ranges of Characteristics Measured in Correlation Study

Characteristic	**Range**
Mixograph	
Mixing time (cm)	4.6–10.9
Peak height (mm)	62.0–83.0
Width (cm)	0.35–1.30
Breakdown (cm)	0.80–1.85
Height at 15 cm (mm)	50.0–63.0
Peak area (cm^2)	12.9–50.5
Contents (%)	
Albumin	8.92–11.43
Globulin	2.62–5.40
Gliadin	29.49–39.20
Glutenin	9.66–19.46
Residue protein	26.05–39.78
	27.38–35.53[a]
Total protein	14.9–17.1
Pentosan	1.73–2.22
Protease activity (absorbance)	0.86–0.95

[a]Determined according to the Orth and O'Brien procedure.

TABLE X
Stepwise Regression Analysis

Characteristic	**Factors Retained in Final Model**	**r^2**
Mixograph mixing time	Residual protein[a] (+); total protein content (−)	0.88
Peak height	Total protein content (+)	0.19
Width	Residual protein[a] (+)	0.65
Breakdown	None	...
Peak area	Residual protein[a] (+); gliadin (+)	0.85
Height (15 cm)	Residual protein[a] (+); total protein content (+); pentosans (+)	0.58

[a]By Orth and O'Brien's procedure.

TABLE XI
Summary of Results from Experiment 1 That Pertain to Effect of Gluten on Height Measurements

		Height		
Starch, Tailings, and Water Solubles[a] from	**Plus Gluten from**	**Peak**	**8-min**	**Protein**
Olaf	Olaf[b]	82.5	69.7	14.6
	F01277			
	Fixed ratio	77.5	61.2	13.4
	Fixed protein content	81.3	64.8	14.4
F01277	F01277[b]	72.5	54.8	13.4
	Olaf			
	Fixed ratio	80.8	68.0	14.6
	Fixed protein content	73.8	63.0	13.5

[a]All according to Olaf fraction ratios.
[b]Standard of ratio or protein content for this half of experiment.

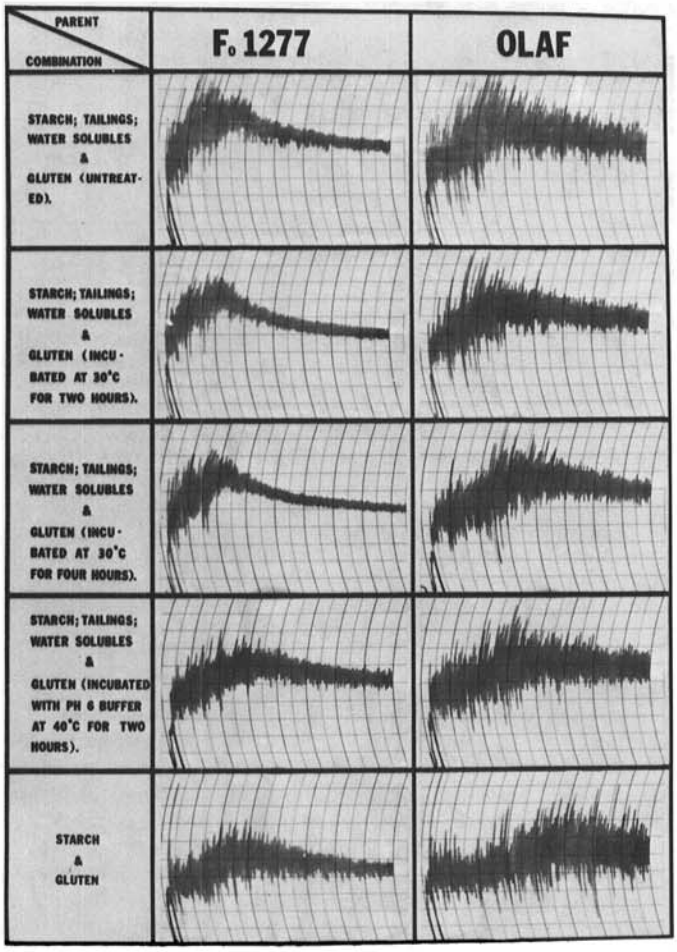

Fig. 4. The effect on mixogram patterns (reconstituted flours) of gluten incubated under various conditions.

development of characteristic varietal patterns under the conditions of mixograph mixing (time and moisture). The effect on the mixograph curve after incubation of F01277 gluten with McIlvaines buffer is probably caused by the buffer rather than by strengthening. Then starch-gluten curves indicate that the characteristic mixing patterns are more likely to result from complex interactions of factors present in all fractions.

We conclude from the preceding studies that the amount of proteases present in normal sound flours are probably very similar and unlikely to exert more than very minor effects on mixing characteristics.

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