Cereal Pentosans: Their Estimation and Significance. II. Pentosans and Breadmaking Characteristics of Hard Red Winter Wheat Flours[1]

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ABSTRACT

Water-soluble, enzyme-extractable, and total pentosans were estimated in 79 hard red winter wheat flour samples representing varietal composites from several locations and three nurseries. The amounts of water-soluble, enzyme-extractable, and total pentosans were significantly and highly correlated. Total protein content was highly correlated with loaf volume but not with water absorption or mixing time. Correlation coefficients among varieties between water-soluble pentosan and protein contents were negative and, generally, significant. Correlation coefficients among varieties between water-soluble, enzyme-extractable, and total pentosan and protein contents, mixing time, and loaf volume were negative and were positive with water absorption; these correlation coefficients were low. Holding water-soluble pentosans constant substantially increased the partial correlation coefficients between protein content and water absorption and loaf volume but not between protein content and mixing time. Holding protein content constant substantially increased the partial correlation coefficients between water-soluble pentosans and water absorption but not between water-soluble pentosans, mixing time, and loaf volume. Those increases were particularly significant in view of the negative correlation between protein and water-soluble pentosans among the varieties. Incorporation of total and, especially, water-soluble pentosans into equations containing protein significantly increased the multiple correlations with water absorption and somewhat with loaf volume and mixing time. It is concluded that water absorption and loaf volume potential (and indirectly mixing time) are governed by protein content and quality, pentosan content and extractability, and their interactions.

Wheat flour contains water-soluble and water-insoluble pentosans. The water-soluble nonstarchy polysaccharides are a mixture of arabinoxylans and arabinogalactans. They constitute about 1% of wheat flour. The water-insoluble pentosans (made up primarily of L-arabinose, D-xylose, and D-glucose) amount to about 2% of the wheat flour. The water-insoluble pentosans are similar to the water-soluble pentosans except for a greater degree of branching.

The water-soluble pentosans gel in the presence of oxidizing agents in a mechanism that involves ferulic acid (Hoseney 1984). The water retention capacity of pentosans exceeds by far that of equal amounts of other wheat flour components (Bushuk 1966). Several researchers have pointed to the detrimental effects of pentosan-rich flour fractions (starch tailings) on loaf volume (Pomeranz 1971). Water-soluble and especially water-insoluble pentosans improve breadmaking properties of European wheat and rye flours (Casier et al 1973). Water-insoluble pentosans impair cookie quality (Yamazaki 1955) and influence the rate of starch retrogradation and bread staling (Kim and D'Appolonia 1977).

Varietal differences in breadmaking potential are generally attributed to differences in functional properties of gluten proteins (Finney 1978). Little is known about the contribution of pentosans to varietal differences in mixing time, water absorption, and loaf volume. Such studies are the subject of this report.

MATERIALS AND METHODS

One group of wheat samples from the Kansas Intrastate Nursery (KIN) consisted of 28 named and experimental varieties, each composited and harvested from St. John, Hesston, Colby, Garden City, Ft. Hays, Caldwell, and Manhattan, KS in 1984. This group was divided into two subgroups of 16 (KIN-A, with a narrow range in water absorption) and 12 (KIN-B, with a wide range in water absorption). A second group, from the 1984 Southern Regional Performance Nursery (SRPN), consisted of 39 named and experimental varieties, each being a composite of equal amounts of grain from Akron, Burlington, Ft. Collins, Ovid, and Walsh, CO; Aberdeen, ID; Colby and Hays, KS; Columbia, MO; North Platte and Sidney, NE; Clovis (dryland and irrigated), NM; Altus, Goodwell, Lahoma, and Stillwater, OK; Brookings, Highmore, and Presho, SD; and Bushland (dryland and irrigated), Chillicothe, and Dallas, TX.

Twelve samples (MISC) consisted of Arkan and Newton harvested at Ottawa, KS in 1984; a TAM-101 composite harvested in Vernon and Bushland, TX in 1983; a composite of an experimental variety, NE78702, harvested in Mead, Clay Center, and N. Platte, NB in 1983; two research selections, KS501097 and Ch^2/Tmp, harvested at Manhattan, KS in 1983; TAM-107 and TAM-108 harvested at Bushland, TX in 1984; Chisholm obtained from Union Equity of Enid, OK; and a Regional Bake Standard (RBS-78) composited from many varieties harvested throughout the Great Plains in 1978.

The three groups of hard winter wheats were analyzed for moisture, ash, protein, bake absorption, bake mixing time, loaf volume, and water-soluble pentosan content. One group (MISC) and one sub-group (KIN-B) were further analyzed for enzyme-extractable and total pentosan contents. Relationships between quality parameters and pentosan contents were determined.

The wheat samples were milled on an experimental mill (Allis-Chalmers Mfg. Co., Milwaukee, WI) to yield straight-grade flours with a 72% extraction and an ash content of 0.45%. Moisture, ash, and protein were determined by AACC methods 44-15A, 08-01, and 46-11, respectively (AACC 1984). Mixing time, baking water absorption, loaf volume, and crumb grain and texture were determined using a straight-dough baking procedure as described by Finney (1984).

Water-soluble, enzyme-extractable, and total pentosan contents were estimated using the procedures of Hashimoto et al (1986).

The orcinol-hydrochloric acid method of Albaum and Umbreit (1947) for pentose determination was used in all pentosan estimations.

Meicellase, a muticomponent enzyme system of *Trichoderma viride* origin included cellulases (I and II), β-glucosidase, xylanases (A and B), β-xylosidase, and α-L-arabinosidase (Hashimoto et al 1971, Hashimoto 1982). Veron HE, a commercial pentosanase, was supplied by Rohm Tech, Inc. (New York, NY). All chemicals were reagent grade.

All determinations were made at least in duplicate and were

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averaged. Least significant differences at the 0.05 and 0.01 levels were 0.157 and 0.209, respectively, for water-soluble pentosans, 0.128 and 0.170 for enzyme-extractable pentosans, and 0.269 and 0.359 for total pentosans.

RESULTS AND DISCUSSION

Ranges of pentosan, protein, bake absorption, bake mixing time, and loaf volume of flours in the KIN-A, KIN-B, MISC, and SRPN groups of flours are given in Table I.

Simple Correlations Among Breadmaking Parameters

The relationships among the water-soluble, enzyme-extractable, and total pentosan are given in Table II as simple correlation coefficients. The relationships of bake absorption, loaf volume, and bake mixing time to the independent variable, protein, for the individual groups as well as all combined are given in Table III. Bake absorption and loaf volume increase as protein increases in a linear fashion with regression slopes characteristic of individual varieties (Finney 1945, 1984). As these groups of flours represented many varieties, poor correlations between protein and absorption or mixing time were not surprising.

Correlations between loaf volume and protein within a variety often approach unity, with each variety characterized by an individual regression slope (Finney 1985). The correlation coefficients for loaf volume versus protein (Table III) were relatively low because many individual slopes were involved. The different slopes for absorption or loaf volume versus protein represent differences in those quality parameters.

Mixing time varies between varieties but is characteristic of a variety containing a 12% or higher protein level, and increases with a protein level below 12% (Finney and Shogren 1972).

The relationships of protein, bake absorption, loaf volume, and bake mixing time to water-soluble pentosan are given in Table IV. Because the trend was for lower pentosan content with increasing protein content among the varieties, the negative relationship between loaf volume and pentosan content might be expected. Water-soluble pentosan (Table IV) predicted bake absorption better than did protein (Table III) within MISC and SRPN.

The relationships of the three pentosan classes to quality parameters in the groups MISC plus KIN-B are given in Table V as simple correlation coefficients. Pentosans (mainly soluble) showed a negative correlation with loaf volume and with protein content. Both enzyme-extractable and total pentosans were positively correlated with water absorption.

The negative correlations between protein and soluble pentosan contents in Table IV and V were established for samples representing, in each case, a great number of varieties. It seems that among varieties as the genetically controlled protein contents increased, pentosan contents decreased. The relationship between protein and pentosan contents (and how they affect breadmaking properties) within a variety is being studied in our laboratories.

Partial Correlations Among Breadmaking Parameters

Correlations for the quality parameter bake absorption versus flour protein (Table III) improved considerably when soluble pentosan was constant (Table VI). Similarly, correlations for bake absorption versus soluble pentosan (Table IV) improved when flour protein was constant (Table VII). The effects on correlations of loaf volume versus protein with soluble pentosan constant and of loaf volume versus soluble pentosan with protein constant were inconsistent. Correlations involving bake mixing time were altered but were also inconsistent.

Among correlations of baking absorption, loaf volume, and

TABLE I
Ranges of Protein Content, Bake Absorption, Bake Mixing Time, Loaf Volume, and Water-Soluble, Enzyme-Extractable, and Total Pentosan Contents of Hard Winter Wheat Flours[a]

Component or Index	KIN-A ($n = 16$)	KIN-B ($n = 12$)	MISC ($n = 12$)	SRPN ($n = 39$)
Protein, %	11.9–13.1	11.2–13.9	9.5–13.0	10.5–12.5
Pentosan, %				
Water-soluble	0.49–0.76	0.43–0.87	0.50–0.97	0.62–1.01
Enzyme-extractable		1.17–1.58	1.16–1.91	
Total		1.32–1.82	1.27–2.09	
Absorption, %	56.2–59.5	55.2–61.7	53.9–64.5	53.4–61.1
Mixing time, min	3.69–7.88	3.57–6.42	2.50–5.94	2.32–7.32
Loaf volume, cm^3	985–1,065	957–1,160	697–985	918–1,025

[a] Flour sources: KIN-A and KIN-B = Kansas Intrastate Nursery, MISC = miscellaneous, and SRPN = Southern Regional Performance Nursery.

TABLE II
Simple Correlation Coefficients of Water-Soluble (SOL) Versus Enzyme-Extractable (ENZ) and Total (TOT) and ENZ Versus TOT Pentosan Contents of Groups of Hard Winter Wheat Flours

	Simple Correlations[a]		
Components	KIN-B	MISC	KIN-B Plus MISC
SOL vs. ENZ	0.45	0.90**	0.77**
SOL vs. TOT	0.84**[b]	0.97**	0.92**
ENZ vs. TOT	0.71**	0.92**	0.88**

[a] Flours: KIN-B = Kansas Intrastate Nursery, MISC = miscellaneous.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

TABLE III
Simple Correlation Coefficients of Bake Absorption, Bake Mixing Time, and Loaf Volume Versus Protein Content for the Groups of Hard Winter Wheat Flours[a]

	Protein vs.					
Index	KIN-A	KIN-B	KIN-AB	MISC	SRPN	ALL
Absorption	−0.20	0.37	0.27	0.43	0.16	0.38**
Mix time	0.45	0.49	0.44*[b]	−0.29	−0.13	0.28*
Volume	0.43	0.85**	0.77**	0.73**	0.36*	0.73**

[a] Flours: KIN-A and KIN-B = Kansas Intrastate Nursery, MISC = miscellaneous, SRPN = Southern Regional Performance Nursery, and ALL = all groups combined.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

TABLE IV
Simple Correlation Coefficients of Protein Content, Bake Absorption, Bake Mixing Time, and Loaf Volume Versus Water-Soluble Pentosan Content for the Groups of Hard Winter Wheat Flours[a]

	Water-Soluble Pentosan vs.					
Component or Index	KIN-A	KIN-B	KIN-AB	MISC	SRPN	ALL
Protein	−0.85**[b]	−0.66*	−0.70**	−0.11	−0.42**	−0.56**
Absorption	0.45	0.31	0.33	0.70*	0.46**	0.27*
Mix time	−0.47	−0.29	−0.39*	0.13	−0.05	−0.35**
Volume	−0.20	−0.31	−0.27	−0.37	−0.22	−0.44**

[a] Flours: KIN-A and KIN-B = Kansas Intrastate Nursery, MISC = miscellaneous, SRPN = Southern Regional Performance Nursery, and ALL = all groups combined.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

TABLE V
Simple Correlations of Water-Soluble, Enzyme-Extractable, and Total Pentosan Versus Flour Protein, Bake Absorption, Bake Mixing Time, and Loaf Volume of Hard Winter Wheat Groups

	Simple Correlations Coefficients in KIN-B Plus MISC[a]		
Component or Index	Water-Soluble	Enzyme-Extractable	Total
Protein	−0.56**[b]	−0.18	−0.25
Absorption	0.27	0.55**	0.54**
Mix time	−0.35	−0.15	−0.30
Volume	−0.44*	−0.31	−0.40*

[a] Flours: KIN-B = Kansas Intrastate Nursery, MISC = miscellaneous.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

bake mixing time, the only large improvements were for loaf volume versus mixing time in MISC when protein was constant (from 0.22 to 0.69) and for loaf volume versus bake absorption when soluble pentosan was constant (from 0.18 to 0.66) (data not given).

Multiple Correlations Among Breadmaking Parameters

Both protein and pentosan contents seemed to govern breadmaking potential of wheat flours. The quality parameters bake absorption, loaf volume, and bake mixing time and their relationships to protein and pentosan contents were analyzed by means of multiple correlations and regressions. Because the three classes of pentosans were included, the analysis was limited to the 24 samples of MISC and KIN-B.

Multiple regression equation intercepts, coefficients, and correlation coefficients were tabulated for bake absorption, bake mixing time, and loaf volume (Table VIII) versus flour protein with soluble, total, and enzyme-extractable pentosan content introduced into the equation in that order.

Both partial and multiple correlations of bake absorption versus protein and pentosan content (Tables VI, VII, and VIII) indicated that both components affect bake absorption. This study did not define the individual roles of soluble, total, and enzyme-extractable pentosans. However, the effect of protein on absorption (Table VIII) is greater when pentosan content is considered especially in light of the negative relationship of pentosan content to protein content among varieties (Table IV).

Bake mixing time was affected more by the combined effects of pentosans and protein than by protein alone (Table VIII; also Tables III, VI, and VII). An indirect effect (involving the relationship between water absorption and mixing time) may be involved.

Loaf volume was greatly affected by both protein and pentosan contents but more so by protein than by pentosan contents (Tables III, VI, VII, and X). The negative relationship of pentosan to protein was reflected by the negative relationship of volume to pentosan (Table V) and the inconsistent relationship of volume to pentosan when protein was constant (Table VII). The limited data indicate that water-soluble pentosans may have a small negative effect on loaf volume (Tables IV and V) and that the total pentosans have an additional negative effect (note the high negative regression coefficients for total pentosans in Table VIII).

Of the 79 samples evaluated, only two represented different locations, and two were from the same location (one dryland and one irrigated). Essentially, then, 75 different varieties were involved in this study. Good correlations between either loaf volume or bake absorption and protein content would be expected within varieties (Finney 1985) but not necessarily among varieties (Table III). As inclusion of pentosan content in partial (Tables VI and VII) and multiple (Table VIII) correlations greatly improved the relationships with protein content, one can conclude that baking quality differences among varieties may not only result from protein content and quality but also from pentosan content and extractability and perhaps their interactions. An additional component that should be considered (directly in its effect on water absorption and indirectly in its effect on mixing time and loaf

TABLE VI
Partial Correlation Coefficients of Bake Absorption, Bake Mixing Time, and Loaf Volume Versus Flour Protein with Water-Soluble Pentosan Constant in Hard Winter Wheat Groups[a]

	Partial Correlation Coefficients, Soluble Pentosan Constant			
Protein vs.	KIN-AB	MISC	SRPN	ALL
Absorption	0.74**[b]	0.71**	0.44**	0.66**
Mix time	0.25	0.29	−0.17	0.11
Volume	0.84**	0.76**	0.30	0.65**

[a] Flour sources: KIN-AB = Kansas Intrastate Nursery, MISC = miscellaneous, SRPN = Southern Regional Performance Nursery, and ALL = all groups combined.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

TABLE VII
Partial Correlation Coefficients of Bake Absorption, Bake Mixing Time, and Loaf Volume Versus Water Soluble Pentosan with Flour Protein Constant in Hard Winter Wheat Groups[a]

	Partial Correlation Coefficients, Flour Protein Constant			
Soluble vs.	KIN-AB	MISC	SRPN	ALL
Absorption	0.76**[b]	0.83**	0.59**	0.62**
Mix time	−0.13	0.10	−0.11	−0.24*
Volume	0.58**	0.43	−0.08	0.05

[a] Flour sources: KIN-AB = Kansas Intrastate Nursery, MISC = miscellaneous, SRPN = Southern Regional Performance Nursery, and ALL = all groups combined.
[b] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

TABLE VIII
Multiple Regression Intercepts, Coefficients, and Correlation Coefficients of Bake Mixing Time, and Loaf Volume Versus Flour Protein and Pentosan Contents for Hard Winter Wheat Flours[a]

	Regression Equation Coefficients[b]					
Parameters	Intercept	P	S	T	E	Correlation[c]
Absorption vs.						
Protein	46.5	0.94				0.381
Pentosan						
Water-soluble	27.2	1.89	7.9			0.691**
Total	25.2	1.80	8.3	1.7		0.833**
Enzyme-extractable	25.0	1.80	9.1	1.2	2.9	0.844**
Mix time vs.						
Protein	0.09	0.37				0.088
Pentosan						
Water-soluble	4.10	0.16	1.70			0.361
Total	4.03	0.32	3.81	3.11		0.428*
Enzyme-extractable	3.89	0.33	4.34	5.09	2.0	0.497*
Loaf volume vs.						
Protein	272	60				0.728**
Pentosan						
Water-soluble	309	58	−16			0.729**
Total	313	77	272	−299		0.880**
Enzyme-extractable	311	77	281	−261	33	0.882**

[a] Flours from the Kansas Intrastate Nursery B groups plus the miscellaneous group.
[b] P = Protein, S = water-soluble pentosans, T = total pentosans, and E = enzyme-extractable pentosans.
[c] * and ** indicate significance at the 0.05 and 0.01 levels, respectively.

volume) is degree of starch damage.

The combined effects of all the above flour components could be used for evaluation of breadmaking potential of wheat flours. It could be used as a basis for developing instrumental methods (i.e., near infrared spectroscopy), in rapid and routine prediction of functional properties of wheats in plant breeding programs, in processing, and in marketing channels.

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