Cereal Pentosans: Their Estimation and Significance. IV. Pentosans in Wheat Flour Varieties and Fractions

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Cereal Chem. 65(3):182–185

ABSTRACT

Total and water-soluble pentosans were determined in flours milled from hard red winter, hard red spring, and soft red winter wheat cultivars grown at various locations and environments; in two sets of commercial air-fractionated flours; and in gluten, starch, and water solubles separated from flours that varied in pentosan contents. There was a negative correlation between protein and soluble pentosan contents. Water absorption and soluble pentosans were correlated, and the correlation coefficient increased if the results were expressed on a constant protein basis. In air-fractionated flours, protein and pentosan contents were correlated positively. Pentosan contents of three flours were related to yields of gluten and prime starch.

The role of pentosans in bread and dough was reviewed by D'Appolonia (1971), and some developments in research on wheat flour pentosans were reviewed by D'Appolonia and Kim (1976). Jelaca and Hlynka (1972) reported that water-soluble pentosans increase resistance of doughs to extrusion. The effect of pentosans was likened to that of iodate. It was postulated that the mechanism producing the pentosan effect likely involves an interaction between gluten and pentosan polysaccharides.

Pentosans associated with gluten were shown by D'Appolonia and Gilles (1971) to be similar to pentosans extracted from flour by water. Pentosans extracted from durum glutens had a greater degree of branching as well as a higher intrinsic viscosity than pentosans extracted from hard red spring (HRS) and soft wheat flour glutens.

Total water solubles and water-soluble pentosans were isolated from pin-milled and air-classified fractions of selected flour streams from three cultivars of HRS wheat (MacArthur and D'Appolonia 1977). The high-protein flour fraction contained the highest amount of water-soluble pentosans.

Variations in pentosan contents were not responsible for bromate requirements in studies conducted by Marais and D'Appolonia (1981). Patil et al (1976) had previously shown that water-soluble pentosans are required to obtain normal loaf volume and that pentosans and bromate, in the absence of other water-soluble components, have an additive effect of overoxidation that causes dough rigidity and reduces loaf volume. It was postulated that rigidity of reconstituted doughs containing pentosans and bromate (and usually characterized by reduced loaf volume) possibly results from a combination of two factors: 1) removal of water-soluble components responsible for gluten-protein extensibility and/or for oxidation requirement (for suppressing the detrimental effect of overoxidation), and 2) oxidation of the pentosan-glycoprotein interaction product.

Previous studies from our laboratories described estimation of pentosans in whole wheat and laboratory-milled wheat products by the orcinol HCl method (Hashimoto et al 1987a). The method was used to estimate pentosans in whole grains, laboratory abraded grains, and pearlings from abraded grains; in commercial samples of brewers' dried grain; and in grain and hulls from cereal grains (Hashimoto et al 1987b). Pentosans were estimated also in 79 hard red winter (HRW) wheat flour samples representing varietal composites from several locations from three nurseries (Shogren et al 1987). Correlation coefficients among varieties between water-soluble pentosan and protein contents were negative and, generally, significant. Incorporation of a water-soluble pentosan into equations containing a protein content term significantly increased the multiple correlations with water absorption and, to a lesser degree, with loaf volume and mixing time.

The negative correlations between protein and soluble pentosans were established for composite samples (from many locations) of a great number of varieties. The results suggested the need to determine the relationship between protein and pentosan contents, as they affect breadmaking properties and as they relate to various flour fractions, within a variety. We report here on the results of such studies.

MATERIALS AND METHODS

Three HRW wheat cultivars (Newton, TAM-101, and Scout 66) were grown in Manhattan, KS, in 1981 and 1982. Two HRW wheat cultivars (TAM-107 and TAM-108) were grown in 1985 at 11 locations throughout the Great Plains. Ten samples of HRS wheats harvested in 1985 were obtained from V. L. Youngs and B. L. D'Appolonia (Fargo, ND), and nine samples of SRW wheats harvested in 1986 were obtained from P. L. Finney (Wooster, OH). The wheats were milled on an Allis-Chalmers experimental mill to produce flours of 68–72% extraction that contained about 0.4% ash.

Centurk 78, an HRW wheat harvested in 1984 in Colby, KS, was milled on an Allis-Chalmers experimental mill as described by Finney and Bolte (1985). The milled products were combined to provide a wide range of products ranging in ash contents from 0.38 to 5.55%.

Two sets of air-classified flours were from commercial sources; one contained four samples and the other six samples.

Three flours were separated into gluten, prime starch, tailing starch, and water-soluble fractions according to the procedure described by Finney (1971). These flours were selected to include a high-pentosan sample (TAM-101 composited from several locations in Texas in 1983); an intermediate-pentosan sample (RBS-78, a composite of flours milled from many wheat varieties from many locations throughout the Great Plains, USA); and a low-pentosan sample (NE-Experimental, from an experimental wheat selection composited from several locations in Nebraska in 1983). Protein contents (%) and bake absorptions (%) were 12.3 and 65.0, 12.1 and 60.5, and 12.3 and 55.0 for TAM-101, RBS-78, and the NE-Experimental, respectively.

Commercial starch, prime starch, and tailing starch were from Manildra Milling Corp., Shawnee Mission, KS.

Pentosan determinations were made as described by Hashimoto

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et al (1987a) and functional (breadmaking) properties as described by Shogren et al (1987). Ash and protein were determined by the AACC methods 08-01 and 46-10, respectively (AACC 1984). All determinations were made at least in duplicate, and all results were averaged. Significance at the 10, 5, and 1% levels is indicated (*, **, and ***, respectively).

RESULTS AND DISCUSSION

Water-soluble pentosans and total protein in flours from three HRW wheats from two crop years are compared in Table I. The soluble pentosans for each variety were fairly constant even though the protein contents varied widely. Previous studies (Shogren et al 1987) indicated that flour from TAM-107 is higher in soluble pentosans than flour from TAM-108. Pairs of TAM-107 and TAM-108 were obtained from 11 locations, and their soluble pentosans and protein contents were determined. The previously observed higher soluble pentosan content for TAM-107 was confirmed (Fig. 1). Negative correlations were obtained for the relation between protein and pentosan contents for TAM-107 ($r = -0.381$), for TAM-108 ($r = -0.575$*), and for the two combined ($r = -0.369$*). When the soluble pentosan content was plotted versus

TABLE I
Protein and Water-Soluble Pentosans in Flours of Three Hard Red Winter Wheats from Two Crop Years

Variety and Crop Year	Protein[a] (N × 5.7, %)	Water-Soluble Pentosans[a] (%)
1981		
Newton	18.0	0.79
TAM 101	18.9	1.10
Scout 66	17.8	0.85
1982		
Newton	9.3	0.77
TAM 101	10.8	1.12
Scout 66	10.3	0.81

[a] 14% moisture basis.

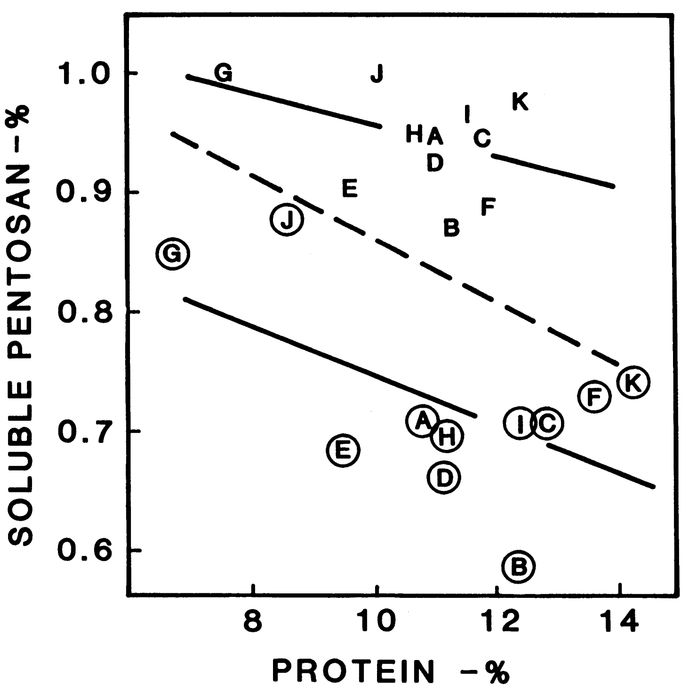

Fig. 1. Plot of protein (%) vs. soluble pentosan (%) in flours from pairs of wheat samples, each from 11 locations. Circled samples TAM-108, noncircled samples TAM-107. Linear regression lines for TAM-108 (bottom) ($r = -0.575$*, $y = -0.021x + 0.96$), TAM-107 (top) ($r = -0.381$, $y = -0.013x + 1.09$), and combined samples (broken line) ($r = -0.369$*, $y = -0.026x + 1.129$).

baking absorption, the correlation coefficient for the combined TAM-107 and TAM-108 samples was $r = 0.643$*** (Fig. 2). The flours comprised two distinct groups with TAM-108 low in soluble pentosans and water absorption and TAM-107 high in soluble pentosans and water absorption. The correlation coefficients between soluble pentosans and baking absorption for each group were low and insignificant ($r = -0.05$ for TAM-108 and $r = 0.162$ for TAM-107). When baking absorption was expressed on a constant protein basis (12.0%), the relationship between soluble pentosans and baking absorption shown in Figure 3 was obtained. The correlation coefficients were 0.530* for the TAM-108 group, 0.461 for the TAM-107 group, and 0.757*** for the combined samples. The results confirmed the contribution of proteins and pentosans to water absorption reported by Shogren et al (1987).

The relationships between pentosans, flour protein, and bake

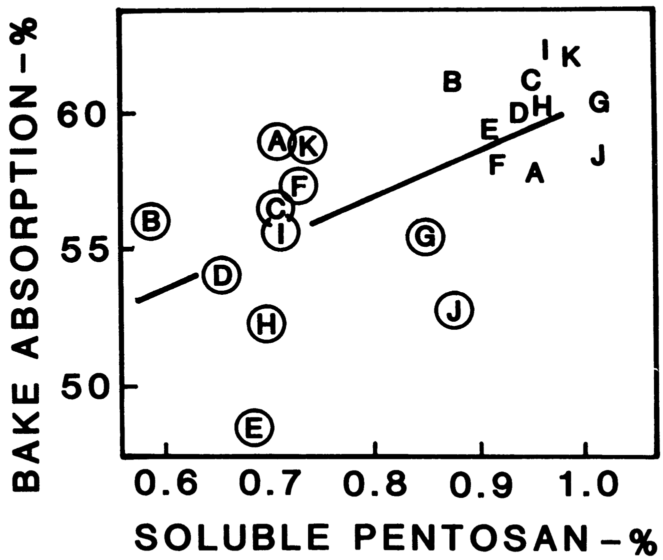

Fig. 2. Plot of soluble pentosan (%) vs. bake absorption (%) in flours from pairs of wheat samples, each from 11 locations. Circled samples TAM-108, noncircled samples TAM-107. Linear regression for combined samples: ($r = 0.643$***), $y = 17.14x + 43.24$.

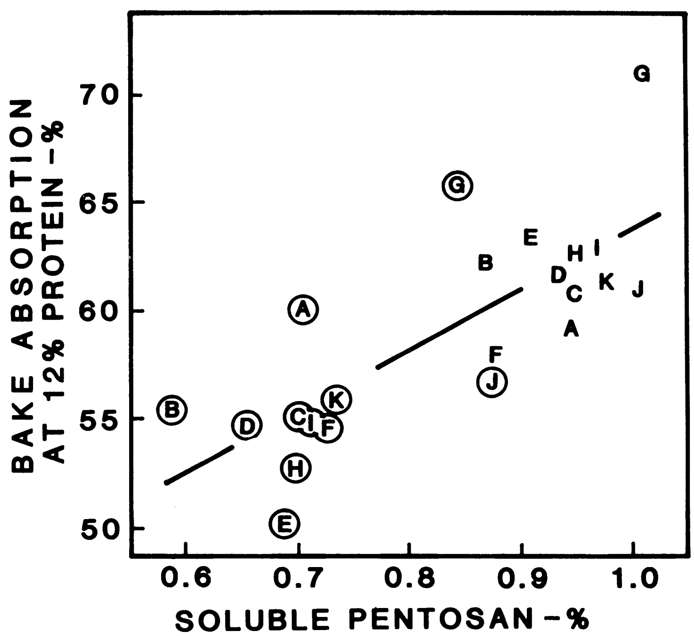

Fig. 3. Plot of soluble pentosan (%) vs. bake absorption (%), in flours from pairs of wheat samples, each from 11 locations, expressed on a 12% protein basis for TAM-108 (circled) and TAM-107 (noncircled) samples. Linear regression for combined samples: ($r = 0.757$***), $y = 27.61x + 36.11$.

absorption were confirmed also for 10 samples of HRS wheat flours. There were significant negative correlations between protein and soluble pentosan ($r = -0.877$**) or total pentosan ($r = -0.703$*). The linear correlation coefficient between soluble pentosan and bake absorption for those 10 HRS wheat flours was insignificant ($r = -0.440$). The coefficient increased to 0.886** when bake absorption was expressed on a constant protein basis.

The linear correlation coefficient between flour protein and soluble pentosan for nine SRW flours was −0.561 (Fig. 4). It is of particular interest that soluble pentosan in three samples of flour milled from the SRW wheat cultivar Abe was almost constant, even though the protein content ranged from 10.2 to 18.4%.

The results indicate, therefore, that soluble pentosans may decrease, increase, or remain fairly constant as protein for a variety increases. The nature and extent to which the relation is affected by location (and environmental conditions), cultural practices, and variety and environment-genetic interaction remain at this time elusive. The relationship probably is complicated by the general negative correlation between protein content and protein solubility; differences in pentosanase activities as affected by variety, location, and growth conditions; and differences between total and soluble pentosans. The results summarized in Table I and Figures 1–3 were obtained for straight grade flours milled experimentally to an extraction of 68–72% and ash contents of about 0.4% (0.32–0.34% in the low-protein and 0.47–0.49% in the high-protein samples). When milling streams were composited to obtain a wide range in protein and ash contents (by inclusion of shorts, red dog, and small amounts of bran), it was possible to obtain a highly significant positive correlation between soluble pentosans and protein contents. Such a relation ($r = 0.960$***) is shown for blends of various streams obtained during the experimental milling of the HRW wheat cultivar Centurk (Fig. 5). The positive correlation resulted, however, from the contribution of pentosans in the outer high-protein kernel layers rich in pentosans (presumably aleurone and germ) rather than from inherent differences in pentosan content of the starchy endosperm. The ash contents of the samples in Figure 5 ranged from 0.38 to 5.55%.

The distribution of soluble and total pentosans in flour fractions separated by air classification was determined. The protein and soluble pentosan contents of two sets of air-classified flours are given in Tables II and III. In each set, soluble pentosans and protein were highly and positively correlated. In one of the commercial sets, we also determined baking absorption and ash (Table III). The correlation coefficients with water absorption were 0.685 for protein, 0.987*** for soluble pentosans, and −0.283 for total pentosans.

The yields and pentosan contents of gluten, starch (prime and tailings), and water-soluble fractions from the high-, intermediate-, and low-pentosan flours are summarized in Table IV and Figure 6. The low-pentosan flour produced the highest yield of gluten and the lowest yield of tailing starch and tailing starch pentosan. Gluten yield decreased and tailing starch yield and its associated pentosan increased as flour pentosan content increased. The limited study indicated that pentosan estimates determined by the orcinol HCl method might be used for rapid, routine prediction of the potential yield of gluten, prime starch, and tailing starch of a flour from a new, experimental wheat selection. Additional samples representing a wide range of wheats will be required to confirm the data and develop predictive equations for estimates of

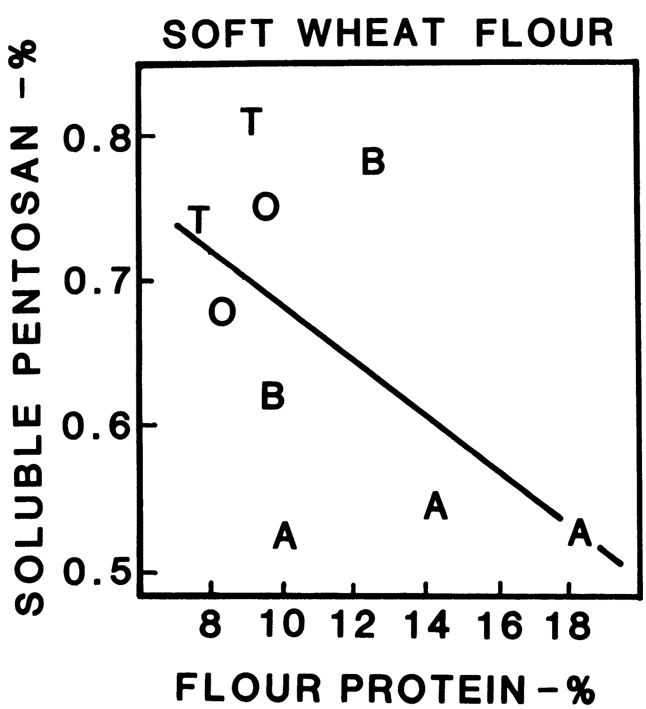

Fig. 4. Plot of flour protein vs. soluble pentosan in nine samples of soft red winter wheat flour, representing four wheats: **A** = Abe; **B** = Beau; **T** = Tyler; and **O** = Ohio Test line ($r = -0.561$, $y = -0.018x + 0.866$).

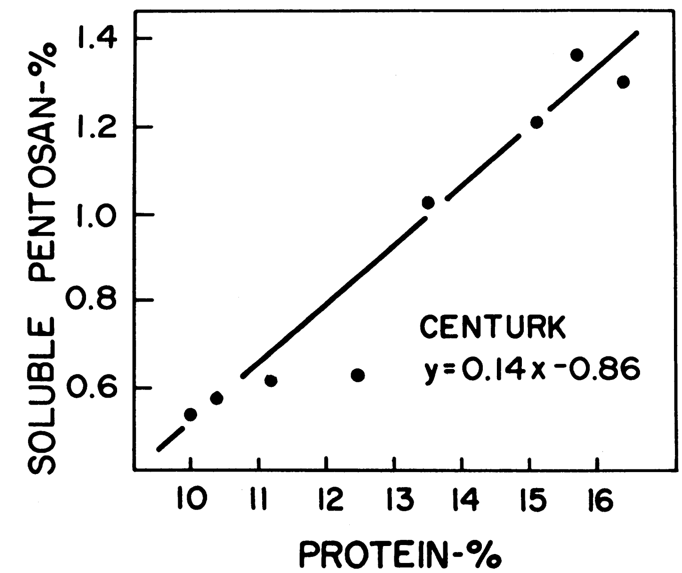

Fig. 5. Plot of soluble pentosan vs. protein in flours and milling by-products from Centurk wheat.

TABLE II
Protein and Pentosan Contents of a Set of Commercially Air-Classified Flours

Flour Description	Protein[a] (N × 5.7, %)	Pentosans[a] (%) Soluble	Total
Original	10.9	0.83	1.86
Bread flour	11.4	0.83	1.66
Low-protein	6.8	0.72	1.42
High-protein	26.8	1.30	1.62

[a] 14% moisture basis.

TABLE III
Protein, Ash, Bake Absorption, and Pentosan Contents of a Set of Commercially Air-Classified Flours[a]

Flour Fraction	Protein (N × 5.7, %)	Ash (%)	Bake Absorption (%)	Pentosan Soluble (%)	Total (%)
Parent	10.0	0.39	62.4	0.94	1.37
Residue	10.4	0.39	63.1	0.95	1.34
High-protein	13.1	0.56	73.5	1.13	1.31
Low-protein	6.9	0.38	56.7	0.79	1.31
Bread flour	11.2	0.45	62.2	0.90	1.49
Fancy grade	12.3	0.60	59.9	0.83	1.46

[a] All data expressed on a 14% moisture basis.

TABLE IV
Pentosan Contents of Three Flours, and Their Gluten, Starch, and Water-Soluble Fractions[a]

Flour and Type	Flour or Fraction Identity	Flour or Fraction Yield (g)	Pentosan Soluble (%)	Pentosan Total (%)	Pentosan Total (g)
TAM 101	Gluten	34.34	0.24	1.14	0.43
(high pentosan)	Prime starch	117.59	0.04	0.59	0.69
	Tailing starch	53.01	0.19	3.76	1.99
	Water soluble	16.29	8.43	8.29	1.35
	(Weighted) sum	221.23	(0.71)	(1.95)	4.37
	Whole flour	250.00	0.79	2.01	5.03
RBS-78	Gluten	37.45	0.18	0.72	0.27
(intermediate pentosan)	Prime starch	144.36	0.04	0.64	0.93
	Tailing starch	44.13	0.21	3.72	1.61
	Water soluble	11.62	9.18	9.23	1.07
	(Weighted) sum	237.56	(0.54)	(1.63)	3.88
	Whole flour	250.00	0.60	1.57	3.93
NE-Experimental	Gluten	38.70	0.26	0.88	0.34
(low pentosan)	Prime starch	141.94	0.05	0.49	0.70
	Tailing starch	38.16	0.24	3.53	1.35
	Water soluble	13.63	8.52	8.24	1.12
	(Weighted) sum	232.43	(0.61)	(1.51)	3.51
	Whole flour	250.00	0.58	1.41	3.53

[a] All data expressed on a 14% moisture basis.

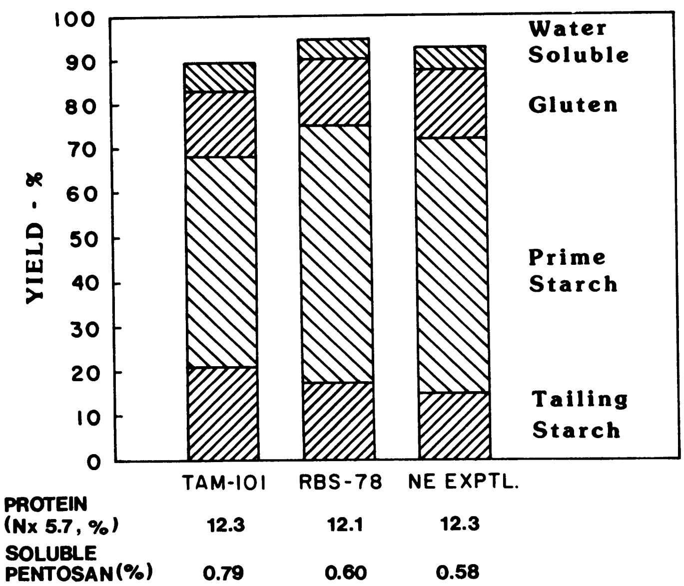

Fig. 6. Yields of tailing starch, prime starch, gluten, and water solubles for three flours that varied in soluble pentosan contents from 0.58 to 0.79% and ranged in protein contents from 12.1 to 12.3%.

gluten and starch yields on the basis of protein and pentosan contents.

The total pentosan contents were 0.39% in prime starch, 2.72% in tailing starch, and 1.46% in total starch from one commercial plant. The pentosan values were lower in commercial than in laboratory preparations, which may have resulted from more effective separation of flour components or from selection of flours low in pentosan and/or better suited for fractionation in commercial processing.

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[Received January 16, 1987. Accepted December 1, 1987.]