WATER-SOLUBLE PENTOSANS OF WHEAT FLOUR. III. EFFECT OF WATER-SOLUBLE PENTOSANS ON LOAF VOLUME OF RECONSTITUTED GLUTEN AND STARCH DOUGHS[1]

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ABSTRACT

Microbaking tests showed that water-soluble pentosans were required to obtain normal loaf volume from reconstituted gluten and starch doughs, and that pentosans and bromate, in the absence of other water-soluble components, had an additive effect of overoxidation, which caused dough rigidity and reduced loaf volume. Diethylaminoethyl (DEAE) cellulose fraction II, a high-molecular-weight glycoprotein, greatly improved loaf volume of gluten-starch loaves in the absence of bromate. Reconstituting the water-soluble pentosans (no bromate), in place of the total water-solubles, produced a loaf-volume-improving effect equal to that of the water-solubles plus bromate. The rigidity of reconstituted doughs containing pentosans and bromate (usually characterized by reduced loaf volume) possibly results from a combination of two factors: a) removal of water-soluble components responsible for gluten-protein extensibility and/or for oxidation requirement (for suppressing the detrimental effect of overoxidation), and b) oxidation of the pentosan-glycoprotein interaction product.

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Finney (1) showed the importance of water-soluble components in the breadmaking performance of wheat flours. Baker *et al.* (2) found that water-soluble pentosans formed an irreversible gel when oxidized. Pence *et al.* (3) reported that omitting soluble pentosans in reconstituted doughs had little effect on baking performance but distinctly modified handling properties of doughs. Tracey (4) found that carbohydrate rather than protein components of pentosan preparations affected breadmaking quality and that adding enzyme preparations presumably containing pentosanase to bread doughs decreased loaf volume. According to Cawley (5), flour-solubles treated with the wide-range proteolytic enzyme pronase still improved the volume of gluten-starch loaves.

D'Appolonia *et al.* (6) studied the baking properties of purified pentosans fractionated by diethylaminoethyl (DEAE) cellulose chromatography. Their fractions I and II, containing arabinose, xylose, and small amounts of proteins, did not enhance the volume of starch-gluten loaves, and had a detrimental effect on crust color. Fractions III, IV, and V, each containing an additional sugar, galactose, and greater amounts of proteins than I and II, improved loaf volume. Hoseney *et al.* (7), using fractionating and reconstituting techniques, showed that potassium bromate improves gas retention by blocking a normal deleterious reaction and that a nondialyzable entity (of the water-soluble fraction) studied

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earlier (8) is required for the bromate reaction.

Those contradictory data on the effects of water-soluble pentosans on baking performance warrant further studies to clarify the role of pentosans in wheat quality. Patil *et al.* (9,10) studied the effects of oxidizing agents on some physical and biochemical properties of water-soluble pentosans. In this paper we report the effect of pentosans on the microbaking properties of reconstituted flour.

MATERIALS AND METHODS

Flour Components Fractionated and Reconstituted

Wheat flour (Scout R-70) was fractionated into gluten, starch, and water-solubles as described by Hoseney *et al.* (7) for baking tests. Protein contents of the lyophilized fractions were determined by the AACC macro-Kjeldahl method (11).

Scout R-70 flour, which contained only 9.5% protein, was fortified with gluten and water-solubles from the same flour, and the fractions were reconstituted to give a protein content of 11.6% as described by Finney (1,12). An 11.6% protein content more effectively differentiated the effects of various pentosan fractions on loaf volume than 9.5% would. Table I illustrates the amount of each fraction reconstituted to give a flour containing 11.6% protein.

Water-soluble pentosans, prepared and purified by the methods of Cawley (5) and Kuendig *et al.* (13), as previously described (9), were fractionated on a DEAE-cellulose column (9). Pentosans, from the water-soluble fraction described by Hoseney *et al.* (8), also were prepared and purified by the methods of Cawley (5) and Kuendig *et al.* (13).

Lyophilized DEAE-cellulose fractions from flour (Scout R-70) pentosans were reconstituted in dry state plus 5 mg ammonium chloride (yeast food, YF) to replace the lost dialyzable water-soluble component (8). Amount of each DEAE-cellulose fraction reconstituted was equal to the α-amylase-treated pentosans present (0.53%) in Scout R-70 flour. Crude pentosans from flour (0.66%) and dough (1.0%) were reconstituted at those levels for baking.

Scout-69 flour, also used as a source of crude pentosans, contained 11.2% protein (14% mb). The use of two flours, Scout-69 and Scout-70, is given by Patil *et al.* (9, p. 45).

TABLE I
Yield, Protein Content, and Amount of Each Scout R-70 Fraction Reconstituted to Give 10 g Flour (14% mb) Containing 11.6% Protein

Flour Fraction	Moisture %	Yield %	Protein as Rec'd %	Amount Reconstituted 14% mb g	Amount Reconstituted As rec'd g
Flour (Scout R-70)	14.5	...	9.5	...	...
Gluten	7.7	9.8	71.5	1.28	1.19
Starch	11.3	85.5	2.3	8.14	7.89
Water-solubles	6.0	4.7	22.5	0.58	0.54
Total				10.00	9.62[a]

[a]Contains 8.6 g dry matter, 1.16 g protein, and 1.02 g water.

Baking Method

The baking procedure of Finney and Barmore (14,15) was adapted by Shogren *et al.* (16) for 10 g of flour. The formula was (on a flour basis in grams): flour 10 (14% mb), sugar 0.6, salt 0.15, shortening 0.3, yeast 0.2, nonfat dry milk 0.4, and 60°L malt syrup 0.05, and water as needed. When water-solubles were not included in starch and gluten blends, yeast food (ammonium chloride, 5 mg) was added to replace dialyzables that contribute to gassing power (8). The straight-dough method, with optimum mixing time, absorption, and potassium bromate (0 to 2 mg), was used. Doughs were fermented 3 hr and proofed 55 min at 30°C. Punching and panning were performed mechanically. Loaves were baked 15 min at 218°C and volumes were measured by dwarf rapeseed displacement.

Each loaf volume in the tables is the average of four replications. A difference of 2.5 cc is statistically significant at the 5% level.

RESULTS AND DISCUSSION

Typical yields, protein contents, and carbohydrate contents (db) of crude and purified pentosans extracted by two techniques from Scout-69 and Scout-70 wheat flours are given in Table II. Additional information on those and other pentosans and their fractions described in Tables III and IV has been published by Patil *et al.* (9,10).

The original flour and reconstituted flour (gluten, starch, and water-soluble fractions G + S + WS) required 20 ppm of bromate for optimum loaf volume (Table III, Fig. 1). Substituting each DEAE-cellulose chromatographic pentosan fraction for the total water-soluble (WS) fraction, however, decreased bromate

TABLE II
Yields, Protein Contents, and Carbohydrate Contents (db) of Crude and Purified Pentosans Extracted by Two Techniques from Scout-69 and Scout-70 Wheat Flours

Pentosans, Source, Extraction Technique, and Treatment	Yield %	Protein[a] %	Carbohydrate[b] %
Scout-69 (Waring Blendor)			
CP[c,d]	0.66	17.6	71.0
AAPP	0.48	16.4	77.4
Scout-70 (Waring Blendor)			
CP[d]	0.66	14.7	76.0
AAPP[d]	0.53	14.5	80.2
Scout-70 (Hand-washed)			
CP[d] of WS	1.16	34.4	54.2
CP[d] of WS, Filtrol treated	0.85	18.4	68.0
AAPP from CP of WS	0.85	30.8	57.0

[a]Protein by micro-Kjeldahl method (AACC methods, 1962).
[b]CHO by phenol-sulfuric acid method of Dubois *et al.* [Anal. Chem. 28: 350 (1956)].
[c]CP, AAPP, and WS are abbreviations for crude pentosans, α-amylase purified pentosans, and water-solubles, respectively.
[d]Used in microbaking.

requirement to 0 ppm. DEAE-cellulose fraction PFII (Table III, Fig. 1), a high-molecular-weight glycoprotein (10,13) responsible for gelation of water-soluble pentosans, gave the highest loaf volume (no bromate), fully equal to the optimums for the controls. Crude pentosans (CP, no bromate) were next best; all other fractions were to varying degrees inferior to CP. Decreased loaf volume resulting from added bromate was attributed to overoxidation of doughs (for example, Fig. 1, D and E).

Crude pentosans from flour (CP/F, Scout-69) and from plain or bromated doughs (rested or nonrested) also showed a pronounced negative loaf-volume response to bromate (Table IV). Although the negative response from bromated doughs (NRBD, RBD) was less than that from plain doughs (NRPD, RPD), the pentosans from plain doughs gave a loaf volume (72 cc) significantly higher than that of the original flour (68 cc). The least functional crude pentosans (CP/RBD and CP/WS/FT, no bromate) gave loaf volumes (66 cc) approaching those of the original flour and control containing WS and bromate. When 20 ppm bromate was added with pentosans from bromated doughs, the reconstituted doughs were characterized by pronounced rigidity (at punch and pan) and overoxidation (reflected in reduced loaf volumes). Jelaca and Hlynka (17)

TABLE III
Baking Absorption, Dough-Mixing Time, and Loaf Volume of Bread Baked from Protein-Fortified Scout R-70 or its Reconstituted Flours Containing Indicated Fractions of Water-Soluble Pentosans

Original Protein-Fortified or Reconstituted Flour	$KBrO_3$ ppm	Loaf Volume cc	Baking Absorption %	Mixing Time min
Original	0	62	65	5-1/2
Original (control)	20	68	65	5-1/2
G + S + WS[a]	0	63	68	6-1/8
G + S + WS (control)	20	69	68	6-1/8
G + S	0	58	69	6-3/4
G + S	20	57	69	6-1/2
G + S + YF + CP	0	67	69	5-3/4
G + S + YF + CP	20	62	69	6-1/8
G + S + YF + AAPP	0	65	69	6-1/8
G + S + YF + AAPP	20	60	69	5-7/8
G + S + YF + PFI	0	64	69	5-1/2
G + S + YF + PFI	20	63	69	5-1/2
G + S + YF + PFII	0	69	70	5
G + S + YF + PFII	20	61	69	4-5/8
G + S + YF + PFIII	0	62	69	6
G + S + YF + PFIII	20	60	69	6-1/4
G + S + YF + PFIV	0	65	69	6-3/8
G + S + YF + PFIV	20	59	69	6-1/2
G + S + YF + PFV	0	62	69	5-3/4
G + S + YF + PFV	20	57	69	6-1/8

[a]G = gluten; S = starch; WS = water-solubles; YF = yeast food (5 mg NH_4Cl); CP = crude pentosans from flour (0.66%, amount used in baking); AAPP = α-amylase-purified pentosans (0.53%); PFI to PF V = DEAE-cellulose chromatographic pentosan fractions (0.53%) eluted with: PFI, water; PFII, 0.0025*M* sodium tetraborate; PFIII, 0.025*M* tetraborate; PFIV, 0.125*M* sodium tetraborate; and PFV, 0.5*N* NaOH.

reported that resistance to extension increased when crude water-soluble pentosans were added to flour.

Gelling ability of pentosans was lost when doughs were rested for 3 hr (9). Yet, loaf volumes of rested and nonrested plain doughs (CP/RPD and CP/NRPD) were equal and highest (72 cc). Thus, the gelling of pentosans does not appear to be related to their functional properties.

Three previous studies (1,7,8) are the basis for using certain fractionating and reconstituting techniques and for understanding and explaining the negative bromate responses. Although the water-soluble fraction is not involved in inherent quality differences (1), it is required to obtain a normal loaf of bread with optimum volume. The role of the water-solubles in baking has been twofold (8): first, the dialyzable fraction is essential for normal gas production, but it can be replaced by suitable yeast food (8) or by ammonium chloride (7); and second, one of the nondialyzable fractions containing the water-soluble pentosans and glycoproteins contributed to gas retention and/or gluten extensibility.

TABLE IV
Baking Absorption, Dough-Mixing Time, and Loaf Volume of Bread Baked from Protein-Fortified Scout R-70 or its Reconstituted Flours Containing Indicated Crude Water-Soluble Pentosans of Scout-69 Flour

Original Protein-Fortified or Reconstituted Flour	$KBrO_3$ ppm	Loaf Volume cc	Baking Absorption %	Mixing Time min
Original	0	62	65	5-1/2
Original (control)	20	68	65	5-1/2
G + S + WS[a]	0	63	68	6-1/8
G + S + WS (control)	20	69	68	6-1/8
G + S + YF + CP/F	0	69	69	5-3/4
G + S + YF + CP/F	20	65	69	5-5/8
G + S + YF + CP/D	0	68	70	5-3/4
G + S + YF + CP/D	20	66	70	5-7/8
G + S + YF + CP/NRPD	0	72	70	5-7/8
G + S + YF + CP/NRPD	20	63	70	6
G + S + YF + CP/RPD	0	72	70	6
G + S + YF + CP/RPD	20	63	70	5-7/8
G + S + YF + CP/NRBD	0	67	70	5-3/4
G + S + YF + CP/NRBD	20	63	70	5-3/4
G + S + YF + CP/RBD	0	66	70	5-5/8
G + S + YF + CP/RBD	20	62	70	5-7/8
G + S + YF + CP/WS[b]	0	68	68	5-1/2
G + S + YF + CP/WS[b]	20	64	68	5-3/4
G + S + YF + CP/WS/FT[b]	0	66	69	5-3/4
G + S + YF + CP/WS/FT[b]	20	60	69	6-1/8

[a]G = gluten; S = starch; WS = water-solubles; YF = yeast food (5 mg NH_4Cl); CP/F = crude pentosans (0.66%, amount found in flour); CP/D = CP/F (1% amount from dough); CP/NRPD = 1% pentosans from nonrested plain dough; CP/RPD = 1% crude pentosans from rested (3 hr at 30° C and 95% RH) plain dough; CP/NRBD = 1% crude pentosans from nonrested bromated dough (1 μeq/g flour); CP/RBD = 1% crude pentosans from rested bromated dough; CP/WS = 1.16% crude pentosans of WS (hand-washing technique); CP/WS/FT = 0.85% crude pentosans of WS (hand-washing technique) after Filtrol treatment (FT).

[b]From R-70 flour.

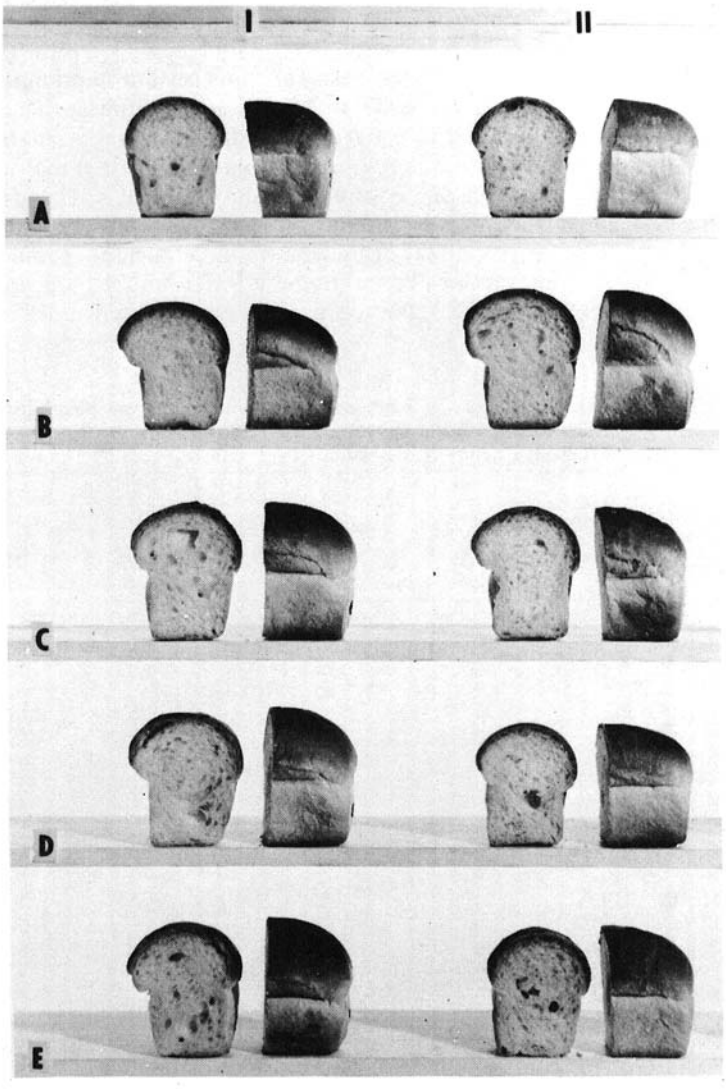

Fig. 1. Cut loaves of bread baked from reconstituted flours in which the water-solubles were replaced by pentosans and yeast food (YF). Loaves were baked with 0 ppm bromate (I) and 20 ppm bromate (II). All loaves contained gluten plus starch. In addition, those in row B contained water-solubles (WS); those in row C, crude flour pentosans (1%, CP/F) plus 5 mg NH_4Cl (YF); those in row D, crude pentosans from nonrested plain dough (1%, CP/NRPD); and those in row E, DEAE-cellulose chromatographic fraction II (0.53%, PFII).

In isolating the pentosans, the dialyzable as well as other nondialyzable components of the water-solubles was discarded, but normal gas production was maintained by adding ammonium chloride to doughs containing gluten, starch, and pentosans. Also, fractionating and reconstituting techniques (7) have shown that potassium bromate improves gas retention by blocking a normally occurring, deleterious reaction associated with a nondialyzable entity from the water-soluble fraction and with both the dialyzable and nondialyzable fractions from the most soluble gluten fraction (pH 6.1 soluble). Additionally, the water-soluble fraction contains a necessary component not found in the pH 6.1 fraction, a component part of crude gluten.

When adding back only the pentosan fraction of the water-solubles of wheat flour, it is not surprising that the component responsible for the bromate reaction or response was omitted, a fact that appears to be clearly documented by the negative bromate responses. The practical effects of pentosans and pentosan fractions on loaf volume are represented by nonbromated doughs because the bromate-requiring entity of the water-solubles was not present.

In our earlier work we used DEAE-cellulose chromatography and uv and ir spectroscopy (10) to demonstrate increased association among carbohydrates, protein components, and pentosans in dough (bromated and iodated). Thus, in the absence of the bromate-requiring entity of the water-solubles, an explanation for the differences in the negative bromate responses is that pentosans and bromate interact with each other and with other flour constituents to increase the resistance of gluten to extension. Excessive rigidity of dough impairs oven spring and dependent loaf volume. When dough extensibility is decreased before starch gelatinizes, gas cells cannot expand before gluten is denatured by the baking temperature.

Thus, microbaking data show that water-soluble pentosans were required to obtain normal loaf volume from reconstituted gluten and starch, and that bromate was not required if the other components of the total water-soluble fraction were omitted.

Two or more of the following reasons may explain why previous studies with pentosans in reconstituted doughs may agree only in part with the present studies: a) bakings were not made with bromate omitted so that the negative bromate responses could be noted in the absence of most of the water-soluble fraction (7), or b) no yeast food was added to maintain normal gas production in the absence of the dialysate of the water-soluble fraction (8), or c) a nonoptimized and lean formula minimized loaf volume differentiation and probably did not permit normal interactions between wheat flour components and added ingredients.

Work remains to be done on pentosans in reconstituted doughs. When the interactions of dough ingredients and flour fractions or components in optimized dough systems are recognized, we believe that past studies will be better understood and, together with future studies, will clearly define the role of pentosans in breadmaking.

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