EFFECT OF WATER-INSOLUBLE PENTOSAN FRACTION OF WHEAT ENDOSPERM ON THE QUALITY OF WHITE BREAD[1]

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ABSTRACT

A pentosan-rich fraction (55% pentosans) isolated from flour tailings was evaluated for its role in breadmaking. One percent of this fraction increased the flour absorption 5.0 to 5.6%, but was without significant effect on the amylogram characteristics and on the extensigraphic properties of doughs. The gas evolution and retention of dough made with pentosans were comparable to those of the controls. Baking tests with pentosans added to a series of flours showed that an increased level of pentosans was responsible for lowered specific volume of breads and increased coarseness of grain. Similar effects of the pentosan fraction were demonstrated with breads made from prime starch-gluten and prime starch-gluten-water solubles systems.

Pentosans of wheat flour endosperm consist of two types which can be classified as *L*-arabino-*D*-xyloglycans, differing in solubility. The water-soluble component is usually called wheat gum because of its gumlike nature (4). The water-insoluble, pentosan-containing fraction has been studied in forms of low purity and called by various investigators amylodextrin (18), squeegee starch (8), and tailings (13) of wheat flour.

The water-soluble fraction has been studied extensively. It was shown that it affects the viscous properties of doughs (21) and forms irreversible gels upon reaction with certain oxidizing agents used as bread improvers (5). The gel-forming properties were shown to depend on the presence of the proteins associated with this fraction (12). Interaction between proteins and pentosans was demonstrated on model systems (22). Technologically, in bread doughs, these gums were found to be of little effect (16) except for reduction of the mixing time (17).

The insoluble pentosans were found to be similar in chemical composition to the soluble component (14). The differences in their physical properties were ascribed to higher branching, molecular shape, and physical entanglement of the molecules (14,15). The insoluble pentosan fraction reduces the cookie spread more than any other fraction separated from soft wheat flour (24). No work has been done with pentosans of this type in relation to breadmaking, although some of their properties may be estimated from the work with flour tailings (7,18).

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This report details the study of the preparation of purified water-insoluble pentosan fraction and its effect on dough properties and bread quality.

Materials and Methods

Flours. Pentosans were isolated from bakers' patent flour, unbleached and improver-free. Flour fractions, gluten, prime starch, and water-solubles for bake tests were prepared from the same flour. For evaluation of the effects of pentosans four additional flours were used, two commercially milled from winter wheat and two from spring wheat blends. Pertinent analytical data at 14% moisture basis are given in Table I.

TABLE I
EFFECTS OF PENTOSANS — ANALYTICAL DATA
(14% moisture basis)

FLOUR	DESCRIPTION	PROTEIN	ASH	PENTOSAN	FARINOGRAPH ABSORPTION	AMYLOGRAM MAXIMUM
		%	%	%	%	*B.U.*
1	Spring wheat, untreated	13.5	0.53	2.76	64.1	over 1,000
2	Winter wheat, bleached, bromated	12.6	0.48	2.21	64.2	530
3	Winter wheat, bleached, bromated	13.0	0.44	2.60	61.6	640
4	Spring wheat, bleached, bromated	11.6	0.42	2.60	61.2	450
5	Spring wheat, bleached, bromated	11.8	0.43	2.50	60.4	670

Preparation of Flour Fractions. Gluten, prime starch, and tailings were prepared by the dough procedure of Bechtel and Meisner (6). Tailings were also prepared by a batter method. In both procedures precautions were taken to keep the temperature throughout the separation process as low as possible (5°–10°C.). The washed-out wet gluten from the dough process was purified by dispersion in 0.01*N* acetic acid using a Waring Blendor (2 min. at high speed) and removing the major portion of starch by centrifugation (10 min. at 450 × *g*). The dispersed gluten was then freeze-dried. Protein of the dry gluten ranged from 79.6 to 82.5% (N × 5.7), moisture 7 to 8%, and pH 5.1 to 5.3. Direct freeze-drying of wet gluten after it was stretched on trays yielded a hard product of inferior baking quality.

The slurry after separation of gluten was centrifuged. The tailings, forming the upper layer, were separated mechanically from the starch and used for preparation of pentosans. The lower layer of prime starch was freeze-dried. Water-solubles were prepared separately from the same flour according to the method of Sollars (20). In the batter method four parts of flour were dispersed in ten parts of water, then centrifuged. The supernatant was discarded and the residue returned for a second dispersion keeping the flour-to-water ratio the same as during the first dispersion. The mixing was done in a propeller-type mixer at 1,725 r.p.m. for 5 min. each time at 5° to 10°C. When centrifuged, prime starch separated at the bottom, gum gluten above, and tailings at the top. The fractions were separated mechanically and tailings were used for pentosan preparation. The lower level of the tailings fraction recovered by either method contained bran particles and was discarded, as the objective of this study was to evaluate the endosperm pentosans only.

Preparation of Pentosans. The procedure for pentosan preparation was essentially that of Yamazaki (24). A water suspension of tailings was passed through a 400-mesh stainless-steel sieve fitted into a container mounted on a laboratory shaker. The residue on the sieve was washed exhaustively with distilled water with the shaker in operation. Tailings made by the batter process yielded a product high in protein because of the difficulty of mechanical separation of the tailings and gluten layers. This was removed by washing the pentosan-rich fraction with $0.03N$ sodium hydroxide. This treatment was not required when the tailings were prepared by the dough process. The pentosan-rich fraction was then lyophilized. It consisted of 54–60% pentosans, 5.3% protein (N × 5.7), and 1.9% lipids on the dry basis. The remainder was mainly starch and cellulose as found by Yamazaki (24) and MacMasters (13). The yield was 15–25 g. per 5.45 kg. flour. To ensure complete rehydration the dry fraction was rehydrated overnight under refrigeration immediately before use.

Further purification of the tailings by the pancreatin digestion procedure of Simpson (19) increased the pentosan content only slightly. Extraction with $0.5N$ sodium hydroxide at room temperature (14), followed by acidification with acetic acid and precipitation with ethanol, gave a white amorphous powder with 69% pentosans and 2.2% protein. Although this treatment raised the pentosan content and lowered that of protein, use of strong alkali was considered undesirable; there is evidence that it causes a slow degradation of the polysaccharide (3) and rupture of complexes of pentosans with other polymeric compounds (2). Although there is no information on the attachment and significance of the proteins associated with the insoluble pentosan fraction, existence of pentosan-protein complexes in the water-soluble fraction from wheat flour was demonstrated by Kuendig *et al.* (11), who showed their significance in gel formation (12).

Physical Measurements. The amylograph was used to determine the effect of pentosans on the gelatinization characteristics of flours and starches. The absorption and mixing characteristics were measured in the farinograph using the constant flour weight procedure (1). Extensigrams were prepared with doughs containing 2% sodium chloride (flour basis). Dough consistency was brought to 500 B.U. in the farinograph. Doughs were mixed to optimum with 2 min. of rest time after the first min. of mixing. The dough was extended after 45-, 90-, 135-, and 180-min. rest periods. The extended dough was remixed and reused for all tests. Extensibility, maximum resistance to extension, and resistance at 5 cm. extension are reported.

Gas Evolution and Retention. According to the Downs method (9), two sets of pressuremeters were used, one for gas evolution and the other one for gas retention. Essentially the AACC procedure (1) was followed to determine the total gas production. The gas retained in the dough was estimated by the residual pressure after absorption of the escaping gas. This was done by placing a 30-ml. beaker with 20 ml. of 23% of potassium hydroxide (w/v) in the pressuremeters. Similar beakers of 20 ml. of a 23% sodium chloride (w/v) solution were introduced into the meters for gas evolution to keep the measurements comparable. Doughs, 99% flour (59.4 g.) and 1% (0.6 g.) pentosan fraction or the same amount of wheat prime starch in the control, were mixed with 1.7% yeast in the National mixer to optimum development (2.5 min.). The water added was the average of optimum absorptions which was used to keep the solids in both dough systems equal. For each determination 20 g. of dough were taken. Gas pressures at 15-min. intervals were recorded and those after 3 hr. of fermentation time are reported.

Evaluation by Bake Tests. All evaluations were conducted with full-size 1-lb. loaves prepared by the sponge and dough procedure. In tests with flour, 1% of the pentosan fraction and 99% flour were mixed. On the basis of this mixture, 2.5% yeast and 0.5% mineral yeast food (Arkady type) were added to the sponge and 6% sucrose, 4% nonfat dry milk, 2% salt, and 2% lard to the dough. The pentosans were studied also in breads prepared from flour fractions. A mix of starch and gluten (both freeze-dried) was adjusted to 12.0% protein. When water-solubles were used they were incorporated at the expense of prime starch (4% on flour-equivalent basis). Minor ingredients were used at the same level as in the flour doughs.

Results and Discussion

Effect on Physical Properties of Flour Doughs. When a dry mix of 99% flour and 1% freeze-dried pentosan fraction was tested on the farinograph, erratic and abnormal farinograms were recorded, indicating poor rehydration of the pentosans. This difficulty was overcome by rehydrating the pentosan fraction overnight with a portion of the absorption water at refrigerated temperature. This preparation gave farinograms which were virtually identical with those given by fresh, nondehydrated pentosan gel, showing that no change of hydration capacity was caused by freeze-drying. This observation was also confirmed with bake tests which will be discussed later. Characteristic data of farinograms are given in Table II.

TABLE II
EFFECT OF THE PENTOSAN FRACTION ON FARINOGRAMS AND AMYLOGRAMS

SAMPLE	ABSORPTION (14% MOISTURE)	PEAK	MIXING TIME	TOLERANCE [a]
	%	B.U.	min.	B.U.
	I. Farinogram values			
99% flour, 1% prime starch	64.1	500	5.0	80
99% flour, 1% pentosan fraction	64.1	700	3.5	120
99% flour, 1% pentosan fraction	70.1	500	5.5	70
	II. Amylogram values			
		TEMPERATURE OF INITIAL RISE		PEAK
		°C.		B.U.
Prime Starch		82–83		705
99% prime starch 1% pentosan fraction		83		700
99% flour 1% prime starch		63–64		790
99% flour 1% pentosan fraction		63–64		750

[a] Drop in curve in 10 min. following the peak.

The pentosan fraction increased the water-absorption requirement of the flour; 1% of the fraction containing 55% pentosans raised the absorption 5.0 to 5.6% above that of the control flour, or 9.1 to 10.0% on the basis of pentosan content. There was no difference in the response of the flours tested to the addition of this fraction. The absorption estimated by farinograph was considered low in actual preparation of experimental doughs; a 10% increase was judged optimum. The hydrophilic nature of this fraction was recognized previously.

Yamazaki (24) found that "purified tailings" (pentosan content 30–65%) absorbed 10 to 16 times its weight of a bicarbonate solution. Sandstedt *et al.* (18) reported that crude tailings had a much greater absorption than the starch. Mixing time and dough stability were unaffected by the addition of pentosans when these properties were compared at equal consistency levels (500 B.U.). Without adjustment of the water absorption, the pentosans increased the consistency from 500 to 700 B.U., and shortened the mixing time considerably, which is typical for mixing of stiff doughs. Pence *et al.* (17) observed that water-soluble pentosans tend to reduce the mixing time of gluten-starch doughs. The failure of the insoluble component to act similarly may be due to the differences in molecular size and degree of branching between these two fractions. This view is supported by the effect of degree of polymerization and branching of dextrans on the farinograms as observed by Wilham *et al.* (23).

The amylograms were prepared with mixtures of flours (99%) and pentosans (1%), or prime starch (1%) as a control. The presence of the increment of pentosans was without significant effect on the peak viscosity of the flour gel or on temperature of initial rise of the curve. Similar experiments with prime starch and pentosan mixtures confirmed these results. Neither the peak viscosity nor the initial rise of the wheat starch curve was changed by the presence of pentosans.

Extensimetric Studies. Table III shows data of extensigrams obtained with various flours. The objective of these measurements was to estimate the extent to which the pentosan-flour interaction alters the extensigraphic properties of the doughs. To this end doughs prepared with 1% added pentosan fraction were compared with those made with prime starch as controls. Comparisons were made at equal consistency levels (500 B.U.) which necessitated an absorption approximately 5% higher than for the control doughs. It is apparent from the values given that there was no appreciable difference between the "pentosan" doughs and the controls of each of the three flours tested. All three responded similarly. Apparently the pentosans gave some measure of support to the flour dough structure, as they increased the water-carrying capacity of the dough without altering its physical properties.

Gas Evolution and Retention. Physical methods of dough evaluation used above did not take the yeast activity into account. To evaluate this factor, gas retention and evolution of doughs with and without pentosans were measured. The values after 3 hr. of fermentation are reported in Table IV. The experimental doughs contained 1% pento-

TABLE III

EFFECT OF THE PENTOSAN FRACTION ON EXTENSIMETRIC PROPERTIES OF FLOUR DOUGHS

Flour	Maximum Resistance				Extensibility				Resistance at 5 cm. Extension			
	(Rest period, min.)				(Rest period, min.)				(Rest period, min.)			
	45	90	135	180	45	90	135	180	45	90	135	180
	B.U.	*B.U.*	*B.U.*	*B.U.*	*mm.*	*mm.*	*mm.*	*mm.*	*B.U.*	*B.U.*	*B.U.*	*B.U.*
	Flour 1 (untreated patent)											
Control[a]	500	833	853	805	207	123	107	99	230	527	643	686
With pentosans[b]	487	813	843	783	197	120	106	97	243	547	666	693
	Flour 2 (winter wheat)											
Control[a]	517	830	880	910	172	104	95	88	277	587	680	783
With pentosans[b]	490	800	869	860	172	105	92	90	281	602	724	744
	Flour 5 (spring wheat)											
Control[a]	414	612	705	695	149	96	80	76	265	518	670	661
With pentosans[b]	403	670	718	730	138	91	75	73	280	560	687	771

[a] 99% flour, 1% prime starch.
[b] 99% flour, 1% pentosan fraction.

TABLE IV

EFFECT OF THE PENTOSAN FRACTION ON GAS EVOLUTION AND RETENTION OF BREAD DOUGHS

Sample	Gas Evolution after 180 Min.		Gas Retension after 180 Min.	
	mm. Hg	%[a]	*mm. Hg*	%[a]
Flour 1 (untreated):				
Control[b]	370	100.0	263	71.1
With pentosans[c]	380	102.7	245	66.2
Flour 2 (winter wheat):				
Control[b]	390	100.0	255	65.4
With pentosans[c]	375	94.2	270	69.2
Flour 5 (spring wheat):				
Control[b]	305	100.0	210	68.9
With pentosans[c]	285	93.4	210	68.9

[a] Percent of evolved and retained gas is based on the pressure of gas evolved by the respective control dough, which was taken as 100.
[b] 99% flour, 1% prime starch.
[c] 99% flour, 1% pentosan fraction.

san fraction, or 1% prime starch in controls. They were prepared by using the average of optimum absorption of the pentosan dough and control of each flour in order to keep the solids and fermentable materials of flour in the doughs equal and the fermentation results comparable. From the values given and from the curves (not shown), it is evident that pentosans did not cause a change of these properties. The unchanged gas-retaining capacity of pentosan doughs was an evidence of unweakened dough structure. These results support the conclusion reached above, based on the extensimetric measurements. The unaltered gas-producing capacity indicates that the pentosan fraction neither enhanced nor inhibited this property. A similar observation was made by Golenkov and Naumova (10), who showed that mucopolysaccharides of rye and amylodextrin fraction of wheat flour did not increase the liberation of carbon dioxide after 3 hr. of fermentation when used in wheat flour doughs.

Baking Studies. The effect of pentosans on the flour performance was tested by adding increments of this fraction to doughs of flour and of flour fractions. The incorporation of this fraction into the doughs was cause of some concern, in view of the initial difficulty experienced with farinograms of the unrehydrated freeze-dried product. Therefore, prior to a systematic evaluation, breads were prepared with the freeze-dried, rehydrated freeze-dried, and freshly isolated pentosan fraction. All performed well. Duplicates gave more uniform results with the wet preparations than with the dry product. For this reason the pentosans were routinely rehydrated for testing.

Effect of Pentosans on Bread Made from Flour. For baking experiments of the effect of pentosans on bread made from flour, 1% of the flour was replaced with pentosan fraction. This was equivalent to approximately 0.55% pure pentosan. As a control, flour with the same amount of prime starch was used. Optimum absorptions were predetermined by taking tests. An absorption 10% higher than that of the flour and prime starch was found optimum for pentosan doughs. Two series of baking tests were made. In one the optimum absorption was used. In the other the same absorption was used, taken midway between the optimum for flour-prime starch and that of flour-pentosans, to permit comparison of loaves with equal solids content. These doughs were satisfactory, as they were still within an acceptable consistency range. The handling properties of all doughs were satisfactory and no weakening due to added pentosans was observed. Within each series the pentosan-containing dough proofed to height in the same time as the corresponding control with prime starch. This indicates that the fermentation, gas retention, and dough strength were not altered prior to the oven stage.

The effects of pentosans became evident during baking, with results on loaf volume, grain, and texture shown in Table V. Loaf volume was lower by approximately 0.5 cu. in. per oz., indicating reduced oven spring. Bread with added pentosans had a coarser grain and the texture lacked the characteristic silkiness. Results with all flours were consistent in these respects.

Effect of Pentosans on Breads Made from Flour Fractions. The pentosan fraction was added at three levels to prime starch-gluten and

TABLE V

EFFECT OF THE PENTOSAN FRACTION ON THE QUALITY OF BREADS MADE FROM COMMERCIAL PATENT FLOURS

FLOUR	OPTIMUM ABSORPTION [a]			EQUALIZED ABSORPTION [b]		
	Spec. Vol.	Grain	Texture	Spec. Vol.	Grain	Texture
	cu. in./oz.			*cu. in./oz.*		
Flour 1 (untreated):						
Control [c]	9.9	v. good	v. good	10.4	v. good	excellent
With pentosans [d]	9.5	good−	good−	9.8	good	v. good
Flour 2 (winter wheat):						
Control [c]	10.0	good+	v. good	10.1	v. good	v. good
With pentosans [d]	9.8	good−	good−	9.7	good−	good−
Flour 3 (winter wheat):						
Control [c]	10.0	good+	v. good	10.4	v. good	v. good
With pentosans [d]	9.6	good−	good−	9.7	good+	good−
Flour 4 (spring wheat):						
Control [c]	10.4	good+	v. good	10.5	v. good	v. good
With pentosans [d]	9.9	good−	good−	10.0	fair	good−
Flour 5 (spring wheat):						
Control [c]	10.3	v. good	v. good	10.8	v. good	v. good
With pentosans [d]	9.2	good+	good−	10.0	fair	good−
All flours:						
Control [c]	10.30	v. good−	v. good	10.44	v. good	v. good
With pentosans [d]	9.60	good−	good−	9.84	good−	good−

[a] Absorption which was judged best for the control and pentosan doughs.
[b] Absorption the same for control and pentosan doughs. It was the average of the optimum absorptions.
[c] 99% flour, 1% prime starch.
[d] 99% flour, 1% pentosan fraction.

prime starch-gluten-water solubles systems, which were used instead of flour in making bread. The controls made from the respective flour fractions without addition of pentosans contained 0.34% residual insoluble pentosans. The specific volumes of breads from these experiments are presented in Fig. 1. Addition of each increment of pentosans to the prime starch-gluten mixture resulted in a gradual decrease of the loaf volume. The internal characteristics of breads were also affected. The quality of crumb grain was rated progressively lower because of its increasing openness. The grain of the control bread was judged "good" and that of the bread with the highest pentosan level "fair." The same effect was observed when a normal level of water-solubles was used. There was no measurable difference in specific volumes of bread between these two systems, so that their response to added pentosans was represented by a single line. The ratings of grain were also similar to those of breads made without added water-solubles. The texture, however, was rated "good," whereas that without the solubles was only "fair." Thus it appears that pentosanase, which was postulated to be present in water-solubles (17), did little to modify the properties of the pentosans.

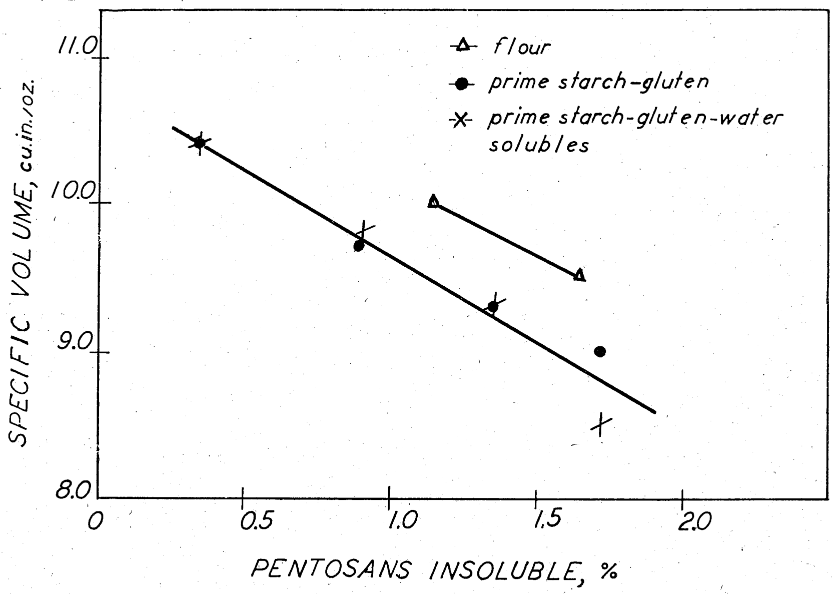

Fig. 1. Effect of insoluble pentosans on the volume of breads made from flour and flour fractions.

When breads from flour fractions were compared with the flour series (Table V), a higher sensitivity of the reconstituted systems seemed to be indicated when these comparisons were based on total pentosan content. There was a closer relationship between the flour and reconstituted systems, however, when only the water-insoluble pentosans were considered. The average content of insoluble pentosans in the flours used was estimated, according to published data (15), to be 1.10%; by addition of the pentosan fraction it increased to 1.65%. These values and the corresponding average specific volumes of breads (taken from Table V) were plotted in Fig. 1. The volumes of breads made from flours were higher at the respective pentosan levels than those made from fractions. This was at least partly due to some decrease of baking properties of the fractions, caused by the separation and reconstitution steps. Further, it may be that the isolated pentosan fraction was not entirely representative of the insoluble pentosans of flour, since by the present method of isolation only partial recovery was attained. The rate of response to the addition of the pentosan fraction was, however, practically equal to that of bread made from flour fractions. These results indicate that the observed adverse effects of pentosans were caused by the water-insoluble portion of pentosans rather than by the entire pentosan component of flour. This interpretation is in general accord with Pence's findings (17) that the water-soluble pentosans were without a significant effect on the quality of breads made from prime starch-gluten mixtures. In contrast, flour tailings which contain the water-insoluble pentosans were found to lower the bread quality (18).

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