Effect of Wheat-Flour Pentosans in Dough, Gluten, and Bread[1]

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ABSTRACT

When water-soluble pentosans, prepared from hard red spring wheat, durum wheat, and a low-grade red spring wheat, were added to flour, a marked increase in resistance to extension in the extensigraph was obtained. The effect of pentosans appeared to be similar to and additive with the effect of iodate. Added pentosans were also shown to produce a decrease in the rate of stretching of gluten in the Kosmina test. Finally, the effect of added pentosans was studied in baking experiments. The water-soluble pentosans had, in general, what may be termed an "improving" effect; a similar but much smaller effect was obtained with the water-insoluble fraction. It is suggested that, although the effect of pentosans appears to be similar to that of iodate, the mechanism producing the effect need not be the same. It likely involves an interaction between gluten and pentosan polysaccharides.

Pentosans constitute a significant component of wheat and flour (1–5). They influence the physical properties of dough and the baking performance of flour (1,5–11) and no doubt have a biological role in the wheat kernel (12). Recently, several investigators (1,4,6,12,13) have reviewed the chemistry of wheat-flour pentosans; and their relation to the rheological properties of dough has been the subject of several reports (3,5,14).

It has been shown that pentosans absorb a large amount of water and have an important effect on the mixing characteristics of dough. Neukom and his associates (1) confirmed the observation of previous workers that pentosans gel upon mild oxidation. Kulp and Bechtel (5) showed that incorporation of insoluble wheat pentosans had no effect on extensigraph properties of dough, but had a detrimental effect on baking properties. Casier and his co-workers (15) showed that insoluble pentosans had a beneficial effect on the baking characteristics of soft wheat flour. Cawley (7) and D'Appolonia et al. (11) reported an increase in the volume of starch-gluten loaves when soluble pentosans were added.

In this laboratory, both water-soluble and water-insoluble pentosan fractions were isolated from three different flours and studies were made to examine the effect of pentosans, using the extensigraph, gluten-stretching, and baking tests.

MATERIALS AND METHODS

The flours used for isolation of pentosan preparations for experiments in this study were from: a milling grade of Canadian hard red spring wheat (CHRS); a low-grade (No. 5) wheat not generally used for flour milling; and No. 2 Canada western amber durum (2 CWAD) wheat, as described previously (14). These flours were selected to obtain pentosans from widely different sources and, therefore, to obtain information that is more broadly based.

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Protein content of the CHRS flour that was used for dough, gluten, and baking tests, as well as for the preparation of pentosans, was 13.7%; and ash, 0.46% (14% m.b.). The farinograph absorption at a consistency of 500 B.U. was 62.8% (14% m.b.).

Both water-soluble and water-insoluble pentosan fractions were isolated by a modified Baker's procedure described in a previous paper. The chemical composition is also given in the same publication (14).

Doughs used for extensigraph tests were mixed in the GRL (Grain Research Laboratory) mixer at 68 r.p.m. and 30°C. for 5 min. in air. All doughs were from CHRS flour and contained 1% sodium chloride (flour basis); the farinograph absorption was reduced by 5 percentage units. Reaction times for doughs were 5 and 30 min., 1, 2, 3, and 4 hr.; and relaxation times in the extensigraph dough holder before stretching were 10 min. for data in Fig. 1, and 15 min. for data in Fig. 2.

Vacuum-dried crude gluten was prepared from CHRS flour as described by Doguchi and Hlynka (16). The method for the study of stretching characteristics of gluten was that originally described by Kosmina (17) and modified by later workers (18,19).

Baking tests were done by the "remix" baking method (20) with 1% water-soluble or water-insoluble crude pentosan fractions added to replace an equal amount of CHRS flour (both calculated on a 14% moisture basis).

RESULTS

Effect of Crude Pentosans on Resistance to Extension in the Extensigraph

Figure 1 summarizes the effect of crude pentosans, both soluble and insoluble, from various sources, when added to strong flour (CHRS) at a level of 1% and tested with the extensigraph. Water absorption used for each dough is given in the graph. The results (left-hand side) show that extensigram height, or resistance to extension, measured at 7 cm., increased very markedly for doughs to which

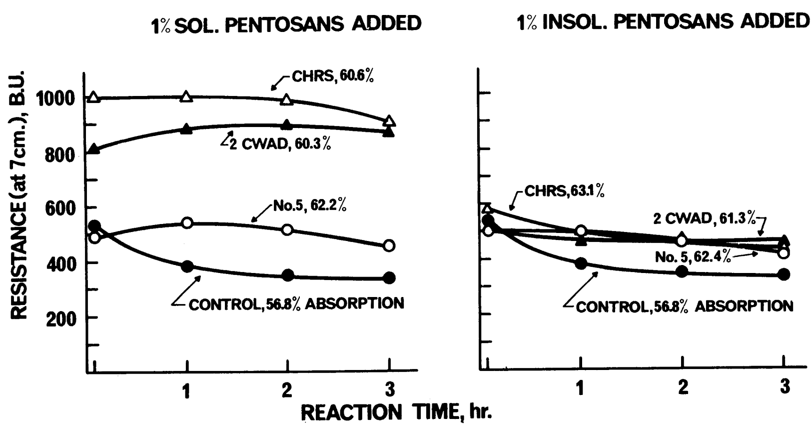

Fig. 1. Graphs showing plots of extensigraph resistance of dough vs. reaction time for 1% water-soluble pentosans added (left), and 1% water-insoluble pentosans added (right).

water-soluble pentosans (4.1% residual protein) from CHRS had been added. Water-soluble pentosans (16.5% residual protein) prepared from 2 CWAD had a similar and almost as large an effect. Water-soluble pentosans (6.8% protein) obtained from a low-grade wheat (No. 5) showed a much reduced, although still positive, effect. This effect of increasing resistance to extension in extensigraph tests was evident at all reaction times in dough from 5 min. to 3 hr. The rheological effect of water-soluble crude pentosans in the extensigraph tests did not appear to be related to the residual protein in the pentosan preparations.

The right-hand half of Fig. 1 shows the results from similar extensigraph tests when 1% of insoluble pentosan fraction was added to flour. It is obvious that the effect on extensigraph properties of the water-insoluble pentosan fraction, although significant, is small. The protein contents of these preparations of 2.9% for CHRS, 13.4% for 2 CWAD, and 6.8% for No. 5 wheat (14) did not appear to indicate a relationship.

The resistance to extension for control doughs shows a general decrease with reaction time. In comparison, doughs containing soluble or insoluble pentosans show a greater stability to changes in extensigraph properties with time. Since heating to boiling temperature was used in the preparation of the pentosan fractions, enzymatic activity would not be expected to play a significant role.

Similar experiments were done with reconstituted doughs, but the results are not shown because they were essentially similar to those already described. It was noticed, however, that for extensigraph tests, reconstituted doughs without pentosans required absorptions equal to their farinograph absorptions. Also, a somewhat longer relaxation time between shaping and stretching the extensigraph test sample was more suitable for such doughs.

Effect on Extensigraph Properties of Pentosans in the Presence of Iodate in Dough

Preliminary experiments were made with the Brabender Extensigraph to examine the effect of pentosans in the presence of iodate in doughs in order to ascertain whether the effect of pentosans was of the same type as that of the well-known improving effect of iodate, and whether there was some obvious interaction or difference between the two effects. Water-soluble and water-insoluble pentosan fractions from CHRS flour were added at a level of 1% (flour basis), and iodate at 10 p.p.m. Water absorptions were adjusted as before. Extensigrams were obtained after the test samples were allowed to relax for 15 min. in the dough holders.

The results, shown as extensigram height at 7 cm. for reaction times of 5 min. to 4 hr., are summarized in Fig. 2. The results shown in the left-hand side of Fig. 2 indicate that 1% of added water-soluble pentosans in flour ($F + P_s$) has an effect about equivalent to that produced by the addition of 10 p.p.m. iodate to flour ($F + I$). It also shows (top curve) that the effect of iodate together with water-soluble pentosans ($F + I + P_s$) on the extensigraph properties of dough appears to be additive. In other words, there appears to be no interaction between the two types of effect. It might be concluded that water-soluble pentosans have an "improving" effect when tested in the extensigraph. The effect was essentially the same, whether iodate and pentosans were added directly to flour and the dough mixed, or iodate and pentosans were first allowed to "react" for an hour and then added to the flour.

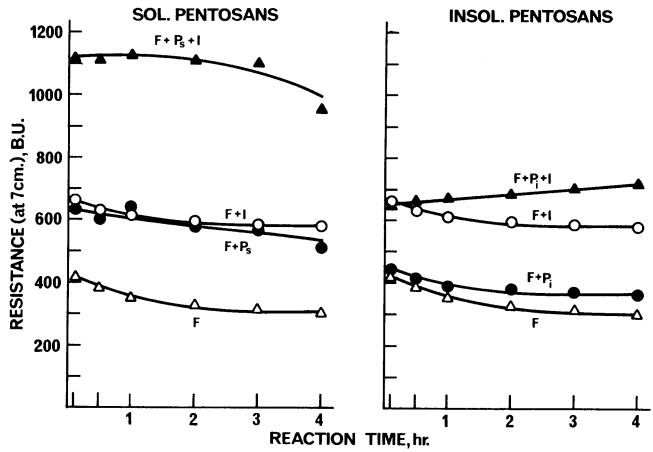

Fig. 2. Plots of dough resistance vs. reaction time showing the effect of added pentosans and iodate added to flour separately (F + P_s; F + I) and together (F + P_s + I) where P_s indicates soluble pentosans, and P_i represents insoluble pentosans in similar experiments.

As already seen in Fig. 1, the effect of water-insoluble pentosans is small but generally parallels that of the water-soluble fraction.

Stretching Characteristics of Gluten with Added Pentosans

The method originally described by Kosmina (17) and modified by Kaminski and Halton (18), and later by Matsuo and Irvine (19), was used in this study to see what effect pentosans might have on stretching characteristics of gluten from a strong-wheat (CHRS) flour. Both water-soluble and water-insoluble pentosan fractions from three different sources were incorporated in amounts of 4% (gluten basis) and 14% m.b., by blending vacuum-dried gluten and pentosans, adding water, mixing, hydrating under water, and then forming the test sample (19).

The results obtained are shown in Fig. 3 as a plot of the extension of gluten vs. extension time. The curves for each kind of pentosan preparation (as designated on the graph) are compared with the gluten control, and with gluten containing iodate.

The results show that, with the exception of the effect of pentosans from low-grade No. 5 wheat, the rate of extension of gluten (i.e. slope of curve) with added pentosans is less than for the gluten control, indicating a strengthening effect on the gluten. The graph also shows that the rate of extension of gluten with added soluble pentosans was less than that of gluten with insoluble pentosans from the same source. The results of these experiments thus confirm, in general, the observation already noted that soluble pentosans had a pronounced effect in extensigraph experiments, while insoluble pentosans had a similar but a smaller effect. It may be pointed out here that the greater effect was obtained with water-soluble pentosans from durum wheat, which also had the higher protein content. This relation, however, is not supported by extensigraph experiments, as already noted.

An experiment in which 10 p.p.m. iodate (gluten basis) was added to the gluten control, has also been included. While the incorporation of iodate had a similar

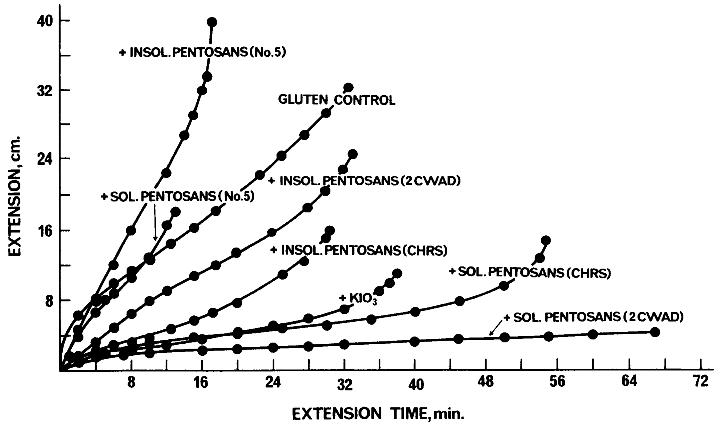

Fig. 3. Plots of amount of extension vs. time of extension for CHRS gluten without and with added water-soluble and water-insoluble pentosans from different sources, and with iodate.

effect to that produced by pentosans in decreasing the rate of gluten stretching, a comparison of the effect only can be made. It is not known, as will be discussed in the last section, whether the mechanism producing the effect is the same.

Baking Experiments

Baking tests were done with 100 g. CHRS flour in which 1 g. of flour was replaced with 1 g. of pentosan preparation (both calculated on a 14% m.b.). Results from these tests are summarized in Table I.

Table I shows that the values for baking absorption were higher by 2 to 3 percentage units for doughs with added pentosans.

All preparations of soluble pentosans improved loaf volume and other loaf characteristics. Best results were obtained with water-soluble pentosans from 2 CWAD, followed by pentosans from No. 5 and CHRS wheats. Here again, the greatest effect was obtained with soluble durum pentosans, which also had the highest residual-protein content. The results, when insoluble pentosans were added, showed a decrease in loaf volume with CHRS pentosans, but an increase with

TABLE I. DATA ON BAKING TESTS WITH DIFFERENT FRACTIONS OF PENTOSANS

Dough	Baking Absorption %	Loaf Volume cc.	Appearance[a]	Crumb Texture[b]	Crumb Color[c]
Control	63	880	8.5	6.5–0	8.5
With 1% sol. pentosans CHRS	65	930	9.0	6.5–0	9.0
With 1% insol. pentosans CHRS	66	850	8.0	6.0–0	9.0
With 1% sol. pentosans No. 5	65	990	8.5	7.0–0	8.5
With 1% insol. pentosans No. 5	66	960	7.5	6.5–0	7.5
With 1% sol. pentosans 2 CWAD	65	1,000	9.0	7.0–0	8.5
With 1% insol. pentosans 2 CWAD	65	930	7.5	7.0–0	7.5

[a,b,c]Appearance, crumb texture, and crumb color scored 0 – 10.

pentosans from the other two sources. The effect of addition of water-insoluble pentosans resulted in a deterioration of other loaf characteristics in most instances. In general, the results, especially those with water-soluble pentosans, are consistent with those obtained by Cawley (7) and those of D'Appolonia et al. (11), in which an increase in loaf volume was attributed to water-soluble pentosans.

DISCUSSION

The results of experiments reported in this paper indicate that crude water-soluble wheat pentosans had a significant effect on extensigraph properties of dough and on the stretching characteristics of gluten, and a less clear-cut effect on bread properties. The effect of the water-insoluble pentosan fraction was minor.

In attempting to assess the role of, especially, the water-soluble crude pentosans, it is necessary to consider the results of the two types of rheological tests and the baking test together. On the whole, the effect of added water-soluble pentosans appears to be analogous to the effect of such improving agents as iodate. The mechanism of the reaction, however, is not clear.

Pence et al. (9) and D'Appolonia et al. (11) suggested that the volume increase resulting from the addition of water-soluble pentosans in the baking test might be attributed to the small amount of protein remaining in the pentosan preparations. Cawley (7), however, obtained increased loaf volumes even when pentosan preparations had been treated with pronase to remove the residual protein. Johansson et al. (21), on the other hand, obtained increases in loaf volume with the addition of commercial pentosanase, but neither the purity of the enzyme, nor the effect of its action on solubilizing the insoluble pentosan fraction, are known. Our data also do not permit a clear conclusion to be drawn from baking tests alone.

The results of rheological tests appear to be more informative. The extensigraph tests clearly indicate that addition of water-soluble pentosans increases the resistance of dough to extension and decreases its extensibility, analogous to results obtained with improving reagents. The effect did not appear to be obviously related to the residual-protein content of the pentosan preparations. In addition, results from gluten-stretching tests point to an interaction between pentosans and gluten. Such interaction would be in accordance with the observations of Cawley (7), who examined the effect of substituted celluloses and other gums. The interaction between gluten and polysaccharides observed by Matsumoto and his associates (22,23) further supports this view. Johansson et al. (24) add another interesting feature to this interaction. They observed that the addition of rye pentosans or rye flour, which is high in pentosan content, decreases the formation of acetic acid-soluble proteins normally released during mixing of dough. In summary, our work, together with that of others, indicates that steady progress is being made towards a better understanding of the function of pentosans in relation to dough, gluten, and bread properties, but that much remains to be done to establish more specifically the role of pentosan compounds.

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