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Effect of Pentosans and Pentosanase on the Baking Quality of Hard Spring Wheats Grown under Diverse Conditions

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INTRODUCTION

The major non-starch polysaccharides of wheat are pentosans, arabinoxylans (AX) as the predominant constituent which originate in the cell walls of the endosperm and bran. Pentosans can be divided into water-extractable pentosans (WEP) and water-unextractable pentosans (WUP). It has been reported that the contents of total pentosans (TP), WEP and WUP in wheat are affected by both genotype and environment (Hartunian-Sowa, 1997; Lempereur et al, 1997; Coles et al, 1997; Li et al, 2002). Pentosans, despite their low content in refined wheat flour, are important in determining bread-making properties as related to water absorption and gluten formation (Courtin and Delcour 2002, Wang et al, 2002, 2003a and 2003b, 2004a and 2004b, 2005). Courtin and Delcour (2002) found that WEP had a positive effect on bread-making and that WUP had a negative effect. Though pentosan modifying enzymes (pentosanases) have been routinely used for over a decade in commercial baking operations, very little published information is presently available regarding pentosan content and the composition of wheat grown under diverse conditions, and how pentosans may affect bread-making performance, efficacy of pentosanases on bread baking performance, and shelf life. The aim of this study was to compare the effects of natural pentosans and the effect of two commercial pentosanase additives with different specificities on bread-making performance and bread firmness on two wheat classes from different crop years.

MATERIALS AND METHODS

Materials

A sample of Canada Western Hard White Spring (CWHWS) wheat and a sample of Canada Western Red Spring (CWRS) wheat from both the 2003 and the 2004 crop years with comparable protein content were provided by the Canadian Wheat Board and milled into straight grade flour on the pilot mill at the Canadian International Grains Institute (CIGI). Two commercial pentosanase preparations (xylanase I which acts on WUP and WEP, xylanase II which acts on WUP only) were used.

Methods

TP of the flour samples were analyzed using the colorimetric method of Douglas (1981). WEP of the flour samples were determined by the method of Lempereur et al (1997) with minor modifications (Wang et al, 2006). WUP were calculated as the difference of TP and WEP.

The baking test was done using the CIGI No Time Dough test baking method (fresh yeast 4%, sugar 4%, salt 2%, whey powder 4%, shortening 3%, ammonium phosphate 0.1%, malt syrup 0.2% and ascorbic acid 60 ppm) and the dough was mixed to 10% past peak as measured by P2M software developed by the University of Manitoba, followed by resting for 20 min, sheeting and molding, proofing for about 60 min (37°C, 85% relative humidity and baking for 20 min (190°C).

Bread score was evaluated using the CIGI Bread Scoring Standard with total bread score (100), including external properties (40: symmetry 10, crust character 10, crust colour 10, break and shred 10) and internal properties (60: crumb colour 20, crumb structure 20, cell wall thickness 5, cell size 5, cell shape 5 and cell distribution 5).

Bread firmness was measured using a TA XT2 Texture Analyzer and following AACC Method 74-09.

Statistical analysis of mean differences was performed using the statistical software SPSS 10.0 for Windows (SPSS Inc., Chicago). Analysis of Variance (ANOVA) was completed using Duncan's multiple comparison for mean difference testing.

RESULTS AND DISCUSSION

Pentosan Content and Composition

The 2003 crop, due to more favourable growing and harvest conditions (warm, dry and well-matured) was considered by industry to be better in quality, which was reflected by higher test weight and falling number, lower ash content and whiter flour colour compared to the 2004 crop which had poorer growing and harvest conditions (cold, wet and late-matured, data not shown). Pentosan content and composition of CWHWS and CWRS straight grade flour samples from both the 2003 and 2004 crop years were analyzed in order to understand how pentosan content and composition are affected by the growing environment. The results of the same wheat classes from the different crop years showed significant variation in the TP, WUP and the ratio of WEP to WUP but not in the WEP. No significant variation in the TP and WUP of different wheat classes from the same year was obtained. The TP and WUP contents were found to be lower and the ratios of WEP to WUP were higher in the samples from the 2003 crop than those in the 2004 crop (Table 1).

Table 1. Pentosan Content and Composition Data

Sample Name	TP (%)	WEP (%)	WUP (%)	WEP/WUP
2003 CWHWS	1.70 ᵃ	0.37 ᵃᵇ	1.33 ᵃ	0.28 ᶜ
2004 CWHWS	2.23 ᵇ	0.42 ᵇ	1.80 ᵇ	0.23 ᵇ
2003 CWRS	1.54 ᵃ	0.36 ᵃ	1.18 ᵃ	0.31 ᵈ
2004 CWRS	2.17 ᵇ	0.38 ᵃᵇ	1.79 ᵇ	0.21ᵃ

Different letters in columns indicate significantly different mean at $P < 0.05$.

Baking Test

All flour samples were treated with xylanase I and xylanase II at the optimum dosages and baked in duplicate using the CIGI No Time Dough test baking method, and subjected to specific volume (SV) and total bread score (TBS) evaluation. The untreated samples were also baked as controls (Tables 2 - 3 and Figure 1).

Table 2. Baking Data of Control Samples

Crop Year	2003		2004	
Wheat Class	SV (cc/g bread)	TBS	SV (cc/g bread)	TBS
CWHWS	7.2 ᶜ	80 ᵇ	6.7 ᵇ	74 ᵃ
CWRS	7.3 ᶜ	80 ᵇ	6.8 ᵃ	76 ᵃ

Different letters in rows indicate significantly different mean at $P < 0.05$.

Table 3. Baking Data of Enzyme Treatments

Treatment	Control		Xylanase I		Xylanase II	
Sample Name	SV (cc/g bread)	TBS	SV (cc/g bread)	TBS	SV (cc/g bread)	TBS
2003 CWHWS	7.2 ᵃ	80 ᵃ	7.4 ᵇ	82 ᵇ	7.8 ᶜ	84 ᶜ
2004 CWHWS	6.7 ᵃ	74 ᵃ	7.2 ᵇ	78 ᵇ	7.6 ᶜ	80 ᶜ
2003 CWRS	7.3 ᵃ	80 ᵃ	7.7 ᵇ	81 ᵃᵇ	7.9 ᶜ	82 ᵇᶜ
2004 CWRS	6.8 ᵃ	76 ᵃ	7.3 ᵇ	78 ᵇ	7.4 ᵇᶜ	80 ᶜ

Different letters in rows indicate significantly different mean at $P < 0.05$.

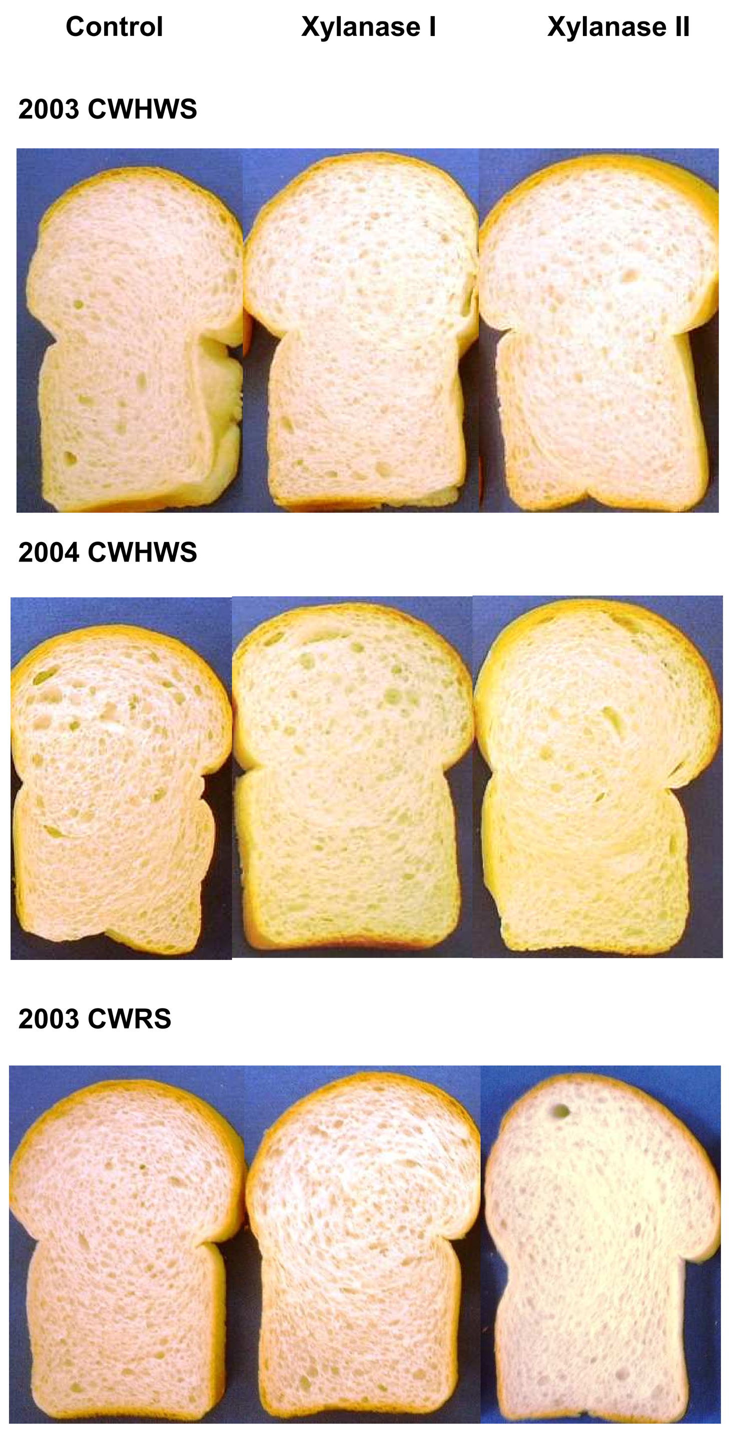

Figure 1. Effect of Xylanases on Loaf Internal Characteristics

The baking results showed that there was significant variation in the bread-making performance of the same wheat class from the different crop years. No significant variation in the bread-making performance of the different wheat classes from the same crop year was found. The 2003 crop exhibited better bread-making performance than the 2004 crop (Table 2). Our results could be explained by the findings of Courtin and Delcour (2002). They found that WEP had a positive effect on bread-making performance and WUP had a negative effect. As the 2003 crop contained lower WUP and higher WEP/WUP than the 2004 crop, this may have contributed to better bread-making performance.

Both xylanases improved the bread-making performance of all wheat samples with larger loaf volume and higher total bread score when compared to the controls (Table 3). However, each enzyme was found to exhibit different functional characteristics between the different crop years and the different wheat classes.

Interestingly, both xylanases demonstrated larger effects on the 2004 crop than the 2003 crop (Figures 2 - 3). This result could be explained by the pentosan content and composition of the samples. Furthermore, xylanase II was found to have a larger effect on improving baking quality than xylanase I which can be explained by their specificities. Xylanase I may catalyze both the conversion of WUP to WEP and the degradation of WEP to lower molecular weight compounds. While xylanase II may only catalyze the conversion of WUP to WEP which might create conditions favorable for improving bread-making performance. As Courtin and Delcour (2002) reported, the optimal xylanase for bread-making would selectively release enzyme-soluble AX from water unextractable AX with a minimal amount of hydrolysis and would have little or no affinity for water extractable AX and enzyme-soluble AX.

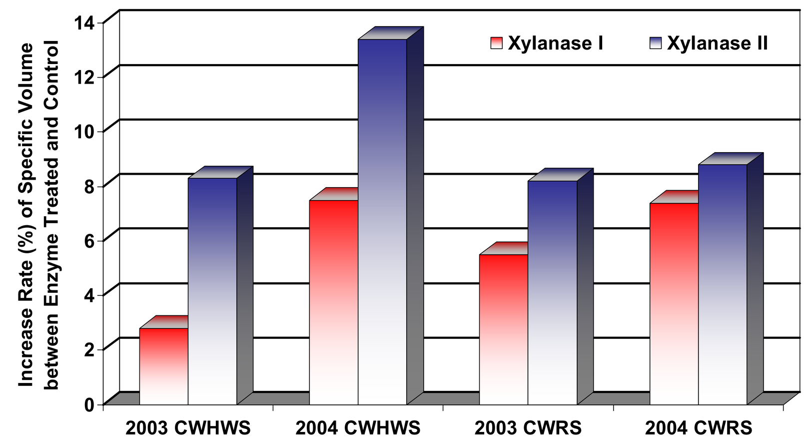

Figure 2. Effect of Xylanases on Bread Specific Volume

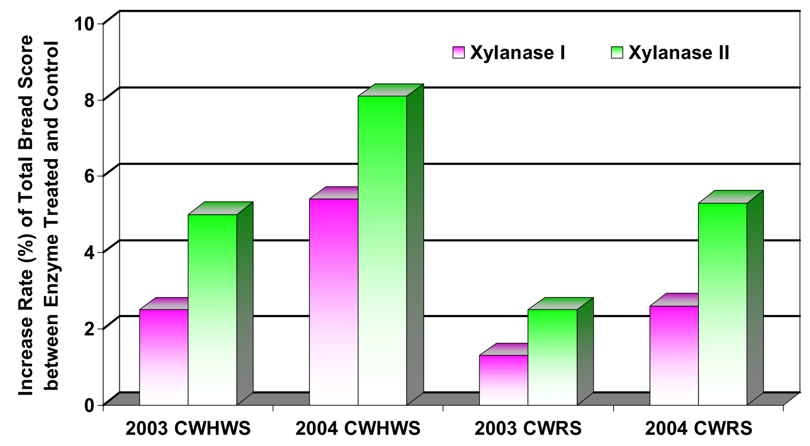

Figure 3. Effect of Xylanases on Total Bread Score

Bread Firmness

Firmness of the bread samples was measured at days 0, 3, 5, 7 to investigate how pentosans and pentosanases affect bread shelf life (Figures 4 - 5). Our results showed that there was significant variation in bread firmness of the control samples. Both xylanases could significantly lower bread firmness and improve bread shelf life of all flour samples. Our results supported the proposals of Forman (2004) who claimed that although it was believed that AX did not play a direct role in the staling process, they could lead to a softer loaf of bread by altering the water holding capacity available to swell the starch granules, thereby softening them. In addition, modification of the arabinoxylan interaction with gluten produced a more continuous, extensible gluten network. The resulting improvements in volume and the aforementioned crumb structure led to loaves with softer texture.

In general, the rates of bread firming (slopes of the curves in Figures 4 – 5) over a one week period were found to be lower for the enzyme-treated flours. Again, the different enzyme preparations exhibited different levels of effects with respect to the different crop years and different classes. Interestingly, xylanase I was found to have a larger effect on reducing bread firming (Figure 6). It is felt that the production of larger amounts of WEP with its smaller molecule weight might retard bread staling through its interaction with the wheat gluten to form hydrated film networks, thereby increasing the water retention of bread, which in turn contributes to a softer textured, less firm bread crumb. However, no significant correlation was found between the rate of bread firming and the natural pentosan content/composition of the flour samples. The explanation presented above is only based on the results for the two wheat classes from the two crop years. Larger sample sizes and pentosan content and composition data of enzyme-treated and control dough and bread samples are required to validate it.

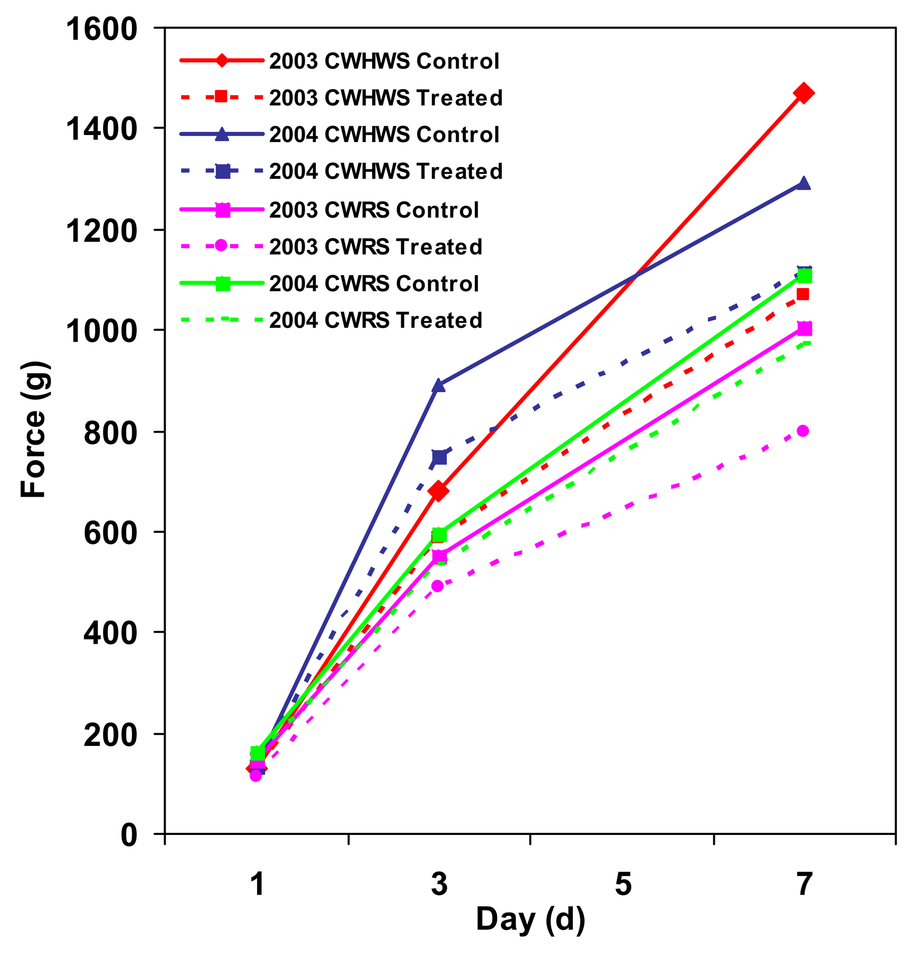

Figure 4. Effect of Xylanase I on Bread Firmness

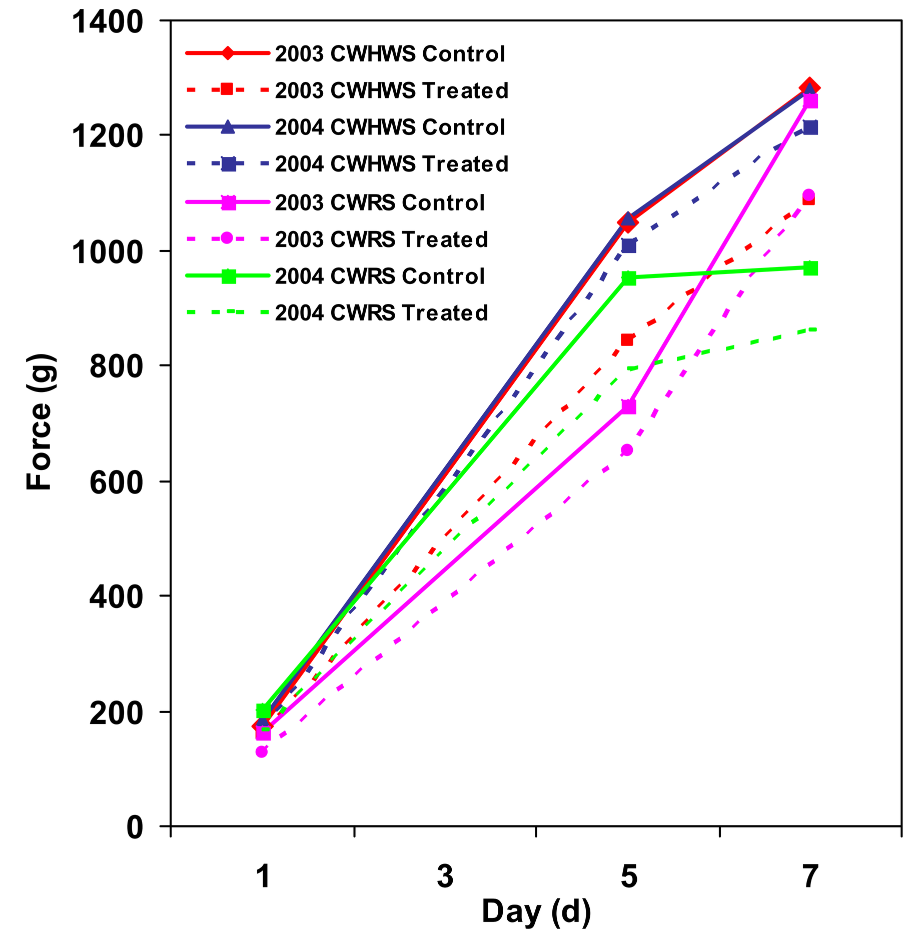

Figure 5. Effect of Xylanase II on Bread Firmness

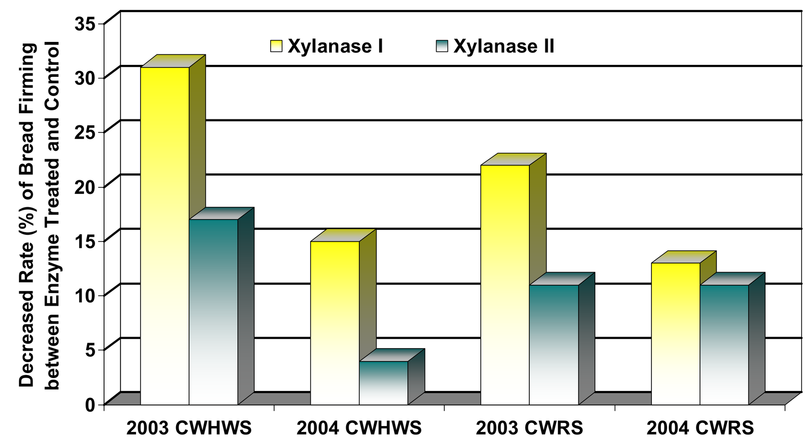

Figure 6. Effect of Xylanases on Decreased Rate of Bread Firming

CONCLUSIONS

There was significant variation in the content and composition of TP , WUP and the ratio of WEP to WUP among the two hard spring wheat classes grown under diverse conditions. Bread-making performance of the samples could be affected by their pentosan content and composition and could be corrected by using pentosanases. The efficacy of pentosanase might depend on both enzyme specificity and crop year. Knowledge of wheat pentosan and pentosanase interactions and their effects would provide commercial bakers, ingredient suppliers, and flour millers with important information that could improve bread and flour quality with respect to variable crop conditions.

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