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# Cell-wall Polysaccharides of Rye-derived Wheats: Investigations of the Biochemical Causes of Dough Stickiness

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*ABSTRACT*

*Rye contains much higher levels of cell-wall polysaccharides such as pentosans and (1→3),(1→4)-β-glucans than wheat, suggesting that these polysaccharides might contribute to the undesirable dough stickiness found in many rye-derived wheats such as those with the IB/IR chromosome translocation. The pentosan and β-glucan content of whole grain and endosperm samples was determined for two varieties of wheat, two of rye and three rye-derived wheats. The pentosan and β-glucan contents of normal and rye-derived wheat were similar. Slightly higher β-glucan levels were detected in the endosperm of the rye-derived wheat samples exhibiting dough stickiness so this character was examined further. Flour produced in a laboratory mill from 18 wheat samples, including 12 rye-derived wheat lines, contained 1·04–2·39% pentosan and 0·14–0·28% β-glucan but the content of these polysaccharides did not show a clear association with the level of dough stickiness. Examination of flour of three varieties of normal wheat grown at each of nine locations showed that there were significant differences in the pentosan and β-glucan content of different varieties of wheat and in the wheat from different sites. The non-starch polysaccharide levels in the flour from rye-derived wheats were within the range found in normal wheats.*

## INTRODUCTION

Plant breeders have introduced parts of rye chromosomes into wheat to enhance disease resistance and other agronomic characteristics. Unfortunately these lines have been found to have undesirable dough properties



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(Zeller *et al.*, 1982; Martin & Stewart, 1986*a*,*b*). The intense dough stickiness and lack of mixing tolerance of these lines has prevented their release as bread wheats in Australia and parts of Europe. The influence of the rye chromosome translocation on the milling and quality characteristics of wheat has been studied (Dhaliwal *et al.*, 1987), but the biochemical causes of the changes in dough surface properties leading to the intense stickiness have not been established.

Rye contains much higher levels of cell-wall polysaccharides (e.g. pentosans and $(1\rightarrow3),(1\rightarrow4)$-$\beta$-glucans) than wheat (Henry, 1985*a*). Pentosans have been widely implicated as important components contributing to the functional properties of wheat flours (Amado & Neukom, 1985; Shogren *et al.*, 1987). These polysaccharides have a high capacity to bind water and effect the absorption of water by the dough. In earlier work (Martin & Stewart, 1986*a*) the pentosan content of one rye-derived line, code numbered QT2870, was compared to that of three wheats not derived from rye. This paper reports a further investigation of the pentosan contents and a study of the $(1\rightarrow3),(1\rightarrow4)$-$\beta$-glucan contents of rye-derived wheat lines in relation to dough stickiness.

## MATERIALS AND METHODS

### Samples

Wheats examined included lines with IB/IR and other chromosome translocations. Endosperm was obtained by hand dissection of grain with a scalpel. Whole grain and endosperm samples were ground in an Ultramat dental amalgamator (Henry, 1987). Flour was produced by milling grain on a Buhler laboratory mill (MLU-202).

### Pentosan analysis

Pentosan was determined by measuring arabinose and xylose by gas chromatography of their alditol acetates (Harris *et al.*, 1988). All results reported are means of duplicate determinations. Arabinose, xylose and glucose were the only monosaccharides present in significant quantities.

### $\beta$-Glucan analysis

$(1\rightarrow3),(1\rightarrow4)$-$\beta$-Glucan was measured from estimation of reducing sugars released by the action of a specific $\beta$-glucanase (EC 3.2.1.73) (Henry & Blakeney, 1986). All results are the mean of duplicate determinations.

### Microscopy of endosperm cell walls

Sectioned grains were stained with Calcofluor (Polysciences Inc.) and examined by macrofluorescence microscopy. Sample preparation procedures were as described previously (Henry, 1985*b*).

### Assessment of dough stickiness

Dough surface properties were assessed on doughs prepared using mixing equipment developed by the Grain Research Laboratory (GRL) of the Canadian Grain Commission. This equipment consisted of a GRL 200 mixer connected to a GRL direct-reading energy input meter and a chart recorder. Doughs were prepared using the formula described by Martin and Stewart (1986*a*). As these doughs were mixed the chart recorder traced a power mixing curve from which the optimum mixing time was calculated. This procedure was then repeated by mixing to this optimum mixing time. The doughs were removed from the mixing bowl and their surface properties were evaluated by assessing the extent to which the dough adhered to the hand (Martin & Stewart, 1986*b*).

## RESULTS AND DISCUSSION

### Pentosan

The rye-derived wheats did not have pentosan contents in the grain as a whole or specifically in the endosperm that were higher than normal wheats (Table 1). Less specific colorimetric methods have been used to determine

**TABLE 1**
Pentosans in Whole Grain and Endosperm of Rye-derived Wheats compared to Normal Wheats and Rye (%)

| | *Whole grain* | | | *Endosperm* | | |
|---|---|---|---|---|---|---|
| | *Arabinose* | *Xylose* | *Total pentosan* | *Arabinose* | *Xylose* | *Total pentosan* |
| Cook (normal wheat) | 2·23 | 4·03 | 5·51 | 0·82 | 1·45 | 2·00 |
| Kite (normal wheat) | 2·46 | 4·50 | 6·12 | 0·83 | 1·51 | 2·06 |
| Benno (rye-derived wheat) | 1·96 | 3·93 | 5·18 | 0·76 | 1·22 | 1·74 |
| Disponent (rye-derived wheat) | 2·09 | 4·02 | 5·38 | 0·67 | 1·38 | 1·80 |
| SUN89D (rye-derived wheat) | 2·30 | 3·97 | 5·52 | 0·93 | 1·78 | 2·38 |
| South Australian rye | 3·36 | 6·67 | 8·83 | 1·55 | 2·77 | 3·80 |
| Canadian rye | 2·77 | 5·30 | 7·10 | 1·33 | 2·22 | 3·12 |

**TABLE 2**
Pentosan and β-Glucan[a] Content of Flour from Three Wheat Varieties (not derived from rye) Grown at Nine Different Sites in Queensland

| *Site* | *Hartog* | | *Kite* | | *Banks* | | *Mean*[a] | |
|---|---|---|---|---|---|---|---|---|
| | *Pentosan* | *β-Glucan* | *Pentosan* | *β-Glucan* | *Pentosan* | *β-Glucan* | *Pentosan* | *β-Glucan* |
| Drillham | 1·32 | 0·24 | 1·06 | 0·35 | 1·35 | 0·17 | 1·24 | 0·25 |
| Gindi | 1·31 | 0·20 | 1·59 | 0·27 | 1·47 | 0·15 | 1·46 | 0·21 |
| The Gums | 1·27 | 0·19 | 1·61 | 0·28 | 1·44 | 0·13 | 1·44 | 0·20 |
| Jambin | 1·21 | 0·33 | 1·40 | 0·37 | 1·43 | 0·22 | 1·35 | 0·31 |
| Jimbour | 1·34 | 0·25 | 1·52 | 0·31 | 2·88 | 0·15 | 1·91 | 0·24 |
| Moura | 1·36 | 0·33 | 1·61 | 0·36 | 1·43 | 0·28 | 1·47 | 0·32 |
| Muckadilla | 1·28 | 0·36 | 1·41 | 0·39 | 1·26 | 0·23 | 1·31 | 0·33 |
| Tummaville | 1·29 | 0·17 | 1·29 | 0·20 | 1·28 | 0·08 | 1·29 | 0·15 |
| Wellcamp | 1·32 | 0·30 | 1·33 | 0·29 | 1·24 | 0·19 | 1·30 | 0·26 |
| Mean[b] | 1·30 | 0·26 | 1·42 | 0·31 | 1·53 | 0·18 | 1·42 | 0·25 |

[a] For β-glucan values least significant difference between sites = 0·04 ($P = 0·05$).
[b] Least significant difference between varieties = 0·02 ($P = 0·05$).

pentosan levels in some of these wheats. Using these methods Martin and Stewart (1986*a*) reported that the pentosan content of flour from a rye-derived wheat line was similar to that in normal wheat flours and Dhaliwal *et al.* (1988) also found normal pentosan levels. Pentosans vary with variety and growing conditions and influence wheat quality (Shogren *et al.*, 1988). Flour pentosan levels in three varieties of normal wheat each from nine locations varied from 1·06 to 2·88% (Table 2). This covered the range found in flour from rye-derived wheats (Table 3). Pentosan levels showed no relationship to the level of dough stickiness. These results suggest that total pentosan levels are unlikely to explain the differences in dough properties in these wheats. The present study further indicates that differences in the arabinose:xylose ratio are not involved in causing stickiness (data not shown).

## β-Glucan

Although the two rye varieties had much higher β-glucan contents than the wheats, the rye-derived wheats on a whole grain basis contained amounts quite similar to the normal wheats (Table 4). However, the rye-derived genotypes producing sticky doughs, Benno and SUN89D, had slightly higher β-glucan levels in the endosperm than the normal wheats but Disponent, a rye-derived variety not showing intense dough stickiness (Zeller, pers. comm.), did not. The total of β-glucan and pentosan in cell walls of the endosperm of rye-derived wheats was similar to the total levels in

**TABLE 3**
Pentosan and β-Glucan Content of Flour from Twelve Rye-derived and Six Normal Wheat Samples

| *Wheat variety/line* | *Pentosan* (%) | *β-Glucan* (%) | *Dough stickiness*[a] |
|---|---|---|---|
| Rye-derived | | | |
| Amigo | 1·41 | 0·24 | VVS |
| Benno | 1·39 | 0·23 | VVS |
| M3344 | 1·26 | 0·27 | VVS |
| Glennson | 1·40 | 0·28 | VS |
| Seri 82 | 1·53 | 0·14 | VS |
| Genaro 81 | 1·28 | 0·25 | VS |
| Ures | 1·21 | 0·28 | VS |
| Substitution line Caribo IB/IR | 1·31 | 0·26 | VS |
| SUN94A | 1·46 | 0·21 | VS |
| QT2870 | 1·21 | 0·18 | VS |
| SUN89D | 1·28 | 0·23 | VS |
| Disponent | 1·49 | 0·21 | NS |
| Not rye-derived | | | |
| Caribo | 1·28 | 0·28 | NS |
| Bennett | 1·04 | 0·22 | NS |
| Oxley | 1·28 | 0·15 | NS |
| Osprey | 1·55 | 0·23 | NS |
| Banks | 1·39 | 0·16 | NS |
| Banks | 2·39 | 0·20 | NS |

[a] Wheats with sticky dough arranged in approximate order of decreasing stickiness.
VVS = very very sticky; VS = very sticky; NS = not sticky.

normal wheats. However, the results suggest that the rye-derived wheats exhibiting dough stickiness have endosperm cell walls with a higher proportion of β-glucan (Table 5).

Examination of sectioned grains stained with Calcofluor revealed the much higher β-glucan content of the rye endosperm cell walls. Rye-derived wheats showed some variation in the intensity of staining of cell walls. However, no consistently greater staining was observed in rye-derived wheats or in wheats with sticky doughs.

The possibility of an association between the β-glucan content of endosperm cell walls and inferior dough properties was investigated by determining the β-glucan content of flours produced in a laboratory mill.

The variation in normal wheats was first determined by measuring the β-glucan content of flour milled from nine different sites. The β-glucan content

**TABLE 4**
β-Glucans in Whole Grain and Endosperm of Rye-derived Wheats compared to Normal Wheats and Rye

| | *Total β-glucan (%)* | |
|---|---|---|
| | *Whole grain* | *Endosperm* |
| Cook (normal wheat) | 0·57 | 0·32 |
| Kite (normal wheat) | 0·53 | 0·21 |
| Benno (rye-derived wheat) | 0·57 | 0·64 |
| Disponent (rye-derived wheat) | 0·61 | 0·21 |
| SUN89D (rye-derived wheat) | 0·70 | 0·54 |
| South Australian rye | 2·02 | 1·34 |
| Canadian rye | 2·31 | 1·73 |

showed genetic and environmental variation ($P = 0{\cdot}01$). Kite generally had the highest β-glucan content and Banks the lowest. Flour of wheat from some sites such as Muckadilla had much more β-glucan than that from others like Tummaville (Table 2). Beresford and Stone (1983) found total β-glucan in *Triticum* grain varied from 0·52 to 1·0%, but did not examine variations due to environment.

Analysis of flour from 12 rye-derived wheat lines and six other wheat varieties indicated that β-glucan levels in the flour of rye-derived wheats were within the range found in normal wheats (Table 3). No clear association between flour β-glucan levels and dough stickiness was apparent.

**TABLE 5**
Pentosan and β-Glucan Contents of Rye-derived Wheats compared to Normal Wheats and Rye (%)

| | *Whole grain* | | *Endosperm* | |
|---|---|---|---|---|
| | *Total pentosan + β-glucan* | *Ratio pentosan/ β-glucan* | *Total pentosan + β-glucan* | *Ratio pentosan/ β-glucan* |
| Cook (normal wheat) | 6·08 | 9·67 | 2·32 | 6·25 |
| Kite (normal wheat) | 6·65 | 11·55 | 2·27 | 9·81 |
| Benno (rye-derived wheat) | 5·75 | 9·09 | 2·38 | 2·72 |
| Disponent (rye-derived wheat) | 5·99 | 8·82 | 2·01 | 8·57 |
| SUN89D (rye-derived wheat) | 6·22 | 7·89 | 2·92 | 4·41 |
| South Australian rye | 10·85 | 4·37 | 5·14 | 2·84 |
| Canadian rye | 9·41 | 3·07 | 4·85 | 1·80 |

## CONCLUSIONS

Since translocation of chromosomes involves the transfer of a large number of genes, rye-derived wheats may express many characters due to genes from rye. Presence of rye characteristics in wheats with quality defects does not establish these characteristics as the cause of the quality problem. These results show that, although some rye-derived wheats may contain slightly higher levels of endosperm $\beta$-glucan, differences in flour $\beta$-glucan levels cannot be used to explain differences in dough properties.

This conclusion suggests that further efforts to characterise the differences in the protein composition of these wheats may be worth while. However, associations between biochemical characteristics and stickiness must be established rather than those between biochemical characteristics and the presence of rye genes.

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