Factors Affecting the Breadmaking Potential of Four Secondary Hexaploid Triticales

L. J. MACRI, G. M. BALLANCE, and E. N. LARTER

ABSTRACT

Factors affecting the breadmaking potential of four secondary hexaploid triticales were examined. Compared to Marquis wheat checks, triticales had lower test weights, higher thousand-kernel weights, and lower flour yields. The weight of dry gluten recovered from the triticle flour varied widely, and all triticle flours had higher levels of α-amylase and exoprotease activity, similar levels of endoprotease activity, and lower gluten protein contents than the wheat flours. Triticle flours showed a direct increase in dry gluten content and gluten protein content, and general improvement in dough strength and loaf volume potential, with increasing protein content. In contrast, there was no apparent relationship between the loaf volume potential and protease activities of the flours. Despite the higher α-amylase activity in the triticle samples, only 4T triticle flour produced bread with a sticky crumb.

Hexaploid triticle (X Triticosecale Wittmack) is a man-made cereal synthesized from durum wheat and rye that is generally inferior to hard red spring wheat for bread production (Haber et al. 1976, Lovoz et al. 1972, Tsen et al. 1973). Past research indicates that the poor baking performance of triticle results in part from an inherently high level of α-amylase and protease activity, and in part from a deficiency of gluten protein quantity and quality (Bushuk and Larter 1980). Recent breeding efforts have produced secondary hexaploid triticales (hybrids derived from triticle × bread wheat crosses) that show stronger mixing characteristics than earlier developed varieties and produce acceptable bread from 100% triticle flour (Lorenz and Welsh 1977, Peña 1984). The objective of the present study was to determine the influence of protein content, α-amylase activity, and protease activity on the breadmaking potential of four secondary hexaploid triticales.

MATERIALS AND METHODS

Triticale and Wheat Samples

The four secondary hexaploid (2n = 42) triticales were chosen to represent material of diverse baking quality. Triticales 4T, 11T, and Impala were obtained from CIMMYT (International Maize and Wheat Improvement Center, Mexico) and have wheat chromosome 2D substituted for rye chromosome 2R (J. P. Gustafson, personal communication). The Canadian triticle Carman carries a full complement of rye chromosomes. One Canadian hard red spring wheat (cultivar Marquis) was included in the study for comparison.

All lines were grown in dryland field plots at the University of Manitoba during the 1983 and 1984 growing seasons. Grain was cleaned on a Carter dPARATOR (2.35-mm sieve), and 50 g of cleaned grain from each sample was ground in a Udy cyclone mill (1.0-mm screen) for whole meal analyses. An additional 2 kg of grain was milled into straight-grade flour on a Buscher laboratory mill. Triticale and wheat samples were tempered overnight to 14.5 and 15.5% moisture, respectively, before milling.

Mature Grain Analyses

Test weight was determined with an Ohaus test weight apparatus. Thousand-kernel weight was calculated from the number of kernels in 20 g of cleaned grain. Pearling resistance was used as an index of kernel hardness. Twenty-gm samples were ground for 20 sec on a Strong Scolter barley pearler according to the method of Obuchowski and Bushuk (1980). The pearling resistance index is the weight of the pearled grain in grams.

Flour and Whole Meal Analyses

Protein (N × 5.7) was determined by the macro Kjeldahl method of Williams (1973) using a TiO₂ catalyst. Enzyme activities were determined according to methods described by Macri et al. (1986). Ash content, sedimentation values, and whole meal falling numbers were determined by AACC methods 08-01, 56-60, and 56-81B (1976), respectively. Damaged starch was measured by the method of Farrand (1964).

Gluten Isolation

Glutens were recovered from 10-g flour samples using a Glutomatic 2100 (Falling Number, Sweden). Gluten balls were freeze-dried and then dried to a constant weight in a 110°C oven for dry weight determinations. Dried gluten was ground with a mortar and pestle, and gluten powder (0.25 g) was analyzed for protein as described above.

Rheological Tests

Farinograms were determined according to AACC method 54-21 (1976) using a constant flour weight of 50 g (14% mb). Extensigrams were determined according to AACC method 54-10 as modified by Holas and Tipples (1978). Water was added to equal farinograph absorption, and doughs were mixed to peak consistency in a large farinograph bowl.

Bake Test

Baking performance was evaluated by the AACC straight-dough method 10-10 (1976). The baking formula included 100 g of flour (14% mb), 3 g of fresh yeast, 1 g of NaCl, and 5 g of sucrose. Malt was omitted. Water was added to farinograph absorption, and triticale and wheat doughs were mixed for 2 and 5 min, respectively, on a GRL mixer. Loaf volume was determined by rapeseed displacement.

RESULTS AND DISCUSSION

Whole Grain Characteristics

All triticle grain samples had lower test weights, higher thousand-kernel weights, lower protein contents, and lower falling number values than the Marquis wheat checks grown in the same year (Table I). The higher protein content of the 1983 samples occurred under the extremely dry growing conditions of that year.

Impala kernels were slightly shrunken at maturity in both 1983 and 1984. Kernel shreling in triticle often indicates abnormal endosperm development and an early termination of starch accumulation (Thomas et al. 1980). The low test weights, higher protein content, and low flour yields (Table II) of Impala are probably related to the poor kernel characteristics of this cultivar.

Flour Characteristics

With the exception of 4T, all triticle flours had lower damaged starch values than the Marquis wheat flours (Table II). It is generally known that the amount of damaged starch in hard wheats

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appears to increase with decreasing protein content (i.e., with increasing starch content), and a similar relationship existed for the triticale samples examined in the present study. For the eight triticale samples (four cultivars over two years) kernel hardness (Table I) and damaged starch values were significantly correlated (r = 0.90, P = 0.01).

All gluts isolated from the triticale and wheat flours were composed of 80–86% protein. The gluten proteins of typical bread wheats account for 78 to 85% of the total flour protein (Pence et al. 1954), and in the present study about 82% of the total protein in the Marquis wheat flours was recovered with the gluten. However, triticale gluts accounted for only 54–71% of the total flour protein. Osborne fractionation studies by Chen and Bushuk (1970) and Wall et al. (1972) have similarly shown that triticale and its parental durum and rye species contain a lower percentage of their total flour protein as glutenlike (i.e., prolamin and glutenin) protein than hard red spring wheat.

The dry gluten content and gluten protein content of the triticale samples was directly related to flour protein content (Fig. 1). The weight of dry gluten recovered from the triticale flours varied widely (7.2–12.7 g/100 g dry flour), and protein analysis of the dry gluts showed that the gluten protein content of the triticale flours was significantly lower than that of the Marquis wheat flours. The lower gluten protein content of the triticale flours was attributable in part to their lower flour protein content (Table I) and in part to the lower percentage of that total flour protein as glutenlike protein.

All triticale flours had lower sedimentation values than the Marquis wheat flours (Table II). Sedimentation values are a measure of the amount of swollen gluten protein and occluded starch in a flour-lactic acid suspension (Zeleny 1971), and the lower sedimentation values of the triticale flours are apparently related to their lower gluten protein content.

Triticale flours contained higher levels of α-amylase and exoprotease (hemoglobinase) than the Marquis wheat flours (Table III). Other investigators have similarly reported that triticale flours have higher α-amylase (Lorenz and Welsh 1977, Peña and Bates 1982) and hemoglobinase (Madl and Tsen 1973, Singh and Katragadda 1980) activity than wheat flours. With the exception of the 1983 Carman and Impala flours, all triticale and Marquis wheat flours contained similar levels of endoprotease activity (Table III).

Rheological Properties and Baking Performance

Typical farinograms and extensigrams are shown in Figure 2. Compared to the Marquis wheat checks, the triticales had lower farinograph absorptions (Table II) and shorter dough development and stability times. Ahmed and McDonald (1974), Haber et al. (1976), and Tsen et al. (1973) have also reported that triticale doughs develop faster and show a poorer tolerance to mixing than bread wheat doughs. Triticale doughs were less resistant to extension than the Marquis bread doughs and therefore expected to have poorer gas retention.

Breads baked from the Marquis wheat flours were superior in overall quality to breads baked from the triticale flours (Fig. 3). Upper crusts of the triticale breads were generally pitted and uneven. The darker crumb color of the Carman and Impala breads was related to the higher ash content (Table II) of these flours. The 4T flours produced bread with a very low loaf volume (Table II).

![Fig. 1. The relationship between the amounts of dry gluten, gluten protein, and total protein (N x 5.7) in the triticale flours. Open symbols (O, □) represent data for the Carman Marquis wheat flours.](image)

| Flavour Composition and Baking Quality Characteristics
<table>
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<tr>
<td>Characteristic</td>
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<td>Flour yield (%)</td>
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<td>Damaged starch (%)</td>
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<td>% Protein (N x 5.7)</td>
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<td>Zeleny sedimentation (cm³)</td>
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<td>Farinograph absorption (%)</td>
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<td>Falling number (sec)</td>
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| Table II

**Whole Grain Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Year</th>
<th>4T</th>
<th>Carman</th>
<th>11T</th>
<th>Impala (Marquis)</th>
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<tbody>
<tr>
<td>Test weight (kg/hl)</td>
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<td>72.3</td>
<td>60.3</td>
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<td>1984</td>
<td>73.9</td>
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<td>72.1</td>
<td>62.0</td>
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<td>1,000-kernel weight (g)</td>
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<td>41.3</td>
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<td>1984</td>
<td>40.8</td>
<td>40.3</td>
<td>37.0</td>
<td>35.1</td>
<td>32.3</td>
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<tr>
<td>% Protein (N x 5.7)</td>
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<td>12.6</td>
<td>13.3</td>
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<td>1984</td>
<td>10.9</td>
<td>12.0</td>
<td>12.5</td>
<td>13.2</td>
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<tr>
<td>Falling number (sec)</td>
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<td>69</td>
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<tr>
<td>1984</td>
<td>62</td>
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<td>98</td>
<td>65</td>
<td>376</td>
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<tr>
<td>Kernel hardness (PRI)</td>
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<td>11.0</td>
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<td>1984</td>
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<td>8.7</td>
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<td>8.6</td>
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**Notes:**
- Average of duplicates; within each row, means followed by the same letter are not significantly different (P = 0.05) by Duncan's multiple range test.
- As is mb.
- PRI = pearing resistance index.
- 14% mb.

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and sticky crumb texture. Carman breads had a tough, thick crust and coarse grain. The loaf volumes of the 11T and Impala breads were the highest among the triticale cultivars examined, and the crumb structure of these breads was generally satisfactory but slightly open in a few loaves.

Factors Affecting the Breadmaking Potential of the Triticale Flours

Protein content. Triticale samples showed a general improvement in dough strength (indicated by increasing sedimentation values, mixing tolerance, and resistance to extension) and loaf volume potential with increasing protein content. For the eight triticale flour samples, there were significant positive correlations between loaf volume and protein content \( r = 0.80, P = 0.05 \), dry gluten content \( r = 0.87, P = 0.01 \), and gluten protein content \( r = 0.88, P = 0.01 \). The higher correlation for loaf volume and gluten protein content indicates that the gluten fraction of the total flour protein had the greater impact on loaf volume potential of the triticale samples.

\( \alpha \)-Amylase activity. In doughs without added sugar, an adequate level of \( \alpha \)-amylase activity is required to provide fermentable sugars to the yeast and to ensure proper gas production. However, an

Fig. 2. Farinograms and extensigrams (135-min stretch) of the 1984 samples.

Fig. 3. Internal loaf characteristics of the straight-dough breads.
increase in amylase activity is not expected to significantly increase the gassing power of a dough if 3–6% sucrose is added to the baking formula (Bloksma 1971). In the present study, dough ingredients included 5% sucrose to minimize the effect that variations in α-amylase activity might have on the loaf volume of the baked breads. While both 4T and Impala flours contained relatively high levels of α-amylase activity (Table III), only 4T flours produced bread with a sticky crumb texture. Wheat flours with a high gluten protein content or low damaged starch values are generally able to tolerate higher levels of α-amylase activity without serious bread quality deterioration. It is possible that the Impala doughs were able to tolerate higher levels of α-amylase activity than the 4T doughs because of the higher gluten protein content and lower damaged starch levels (Table II) in the Impala flours.

There was no discernible difference in crust color among the triticate breads even though α-amylase activity varied widely among the triticate flours. Apparently any increase in sugar production caused by high α-amylase activity (and hence darkening of the crust through browning reactions occurring in the oven) was masked by the level of sucrose added to the baking formula.

**Exoprotease (hemoglobinase) activity.** For the eight triticate flour samples examined, the correlation between loaf volume and exoprotease activity was not significant (r = 0.57, P = 0.05). This result differs from the findings of Singh and Katragadda (1980), who reported a significant negative correlation between loaf volume and triticate hemoglobinase activity (r = -0.85, P = 0.05). It should be noted, however, that Singh and Katragadda also reported a negative correlation between loaf volume and flour protein content (r = -0.50). For the triticate flours examined in the present study, loaf volume and protein content were positively correlated (r = 0.80).

**Endoprotease (azocaseinase) activity.** There was no apparent relationship between the endoprotease activity and loaf volume potential of the triticate flours. The correlation between loaf volume and flour endoprotease activity was not significant (r = 0.12, P = 0.05), and the loaf volume of the triticate breads varied widely in 1984 (Table II) even though there was no significant difference in endoprotease activity among the 1984 triticate flour samples (Table III).

Studies by Hanford (1967) and Redman (1971) have shown that proteolytic activity measured by the release of trichloroacetic acid soluble nitrogen from hemoglobin does not correlate well with gluten softening, and that cleavage of internal peptide bonds by endoproteases are primarily responsible for changes in the physical properties of gluten proteins. In the present study extensigrams of the 4T and Carman doughs were very similar for the 45 and 135 min stretches, whereas 11T and Impala doughs showed a definite decrease in extensibility and increase in resistance to extension at the 135-min stretch, i.e., 11T and Impala doughs became “tighter” with time. In the bake test, triticate doughs did not soften during fermentation. These results indicated that endoproteolytic cleavage of the gluten protein matrix during fermentation was limited. This does not, however, exclude the possibility that gluten proteins may have been altered in situ during kernel development. Although Impala flours contained higher quantities of gluten protein than 11T flours, there was no significant difference in the loaf volume of the 11T and Impala breads in both 1983 and 1984 (Table II). It was also observed that developing Impala kernels had higher levels of endoprotease activity than developing 11T kernels (Macri et al. 1986). According to McDonald and Chen (1964), enzymatic splitting of only a few strategic peptide bonds might detrimentally affect the baking potential of a flour, and it is possible that the higher gluten protein content of Impala was offset by its higher endoproteolytic activity in the developing kernels (with subsequent deterioration of gluten protein quality). To prove or disprove that the baking potential of a triticate can be altered enzymatically during grain maturation is worthy of further investigation.

**CONCLUSIONS**

It was concluded that flour protein content was a major factor controlling the dough strength and loaf volume potential of the four secondary triticales examined. Loaf volume was highly correlated with flour protein content, and dry gluten and gluten protein contents of the triticate samples increased directly with flour protein content. The inferior baking performance of the triticate flours was apparently related to a deficiency in protein quantity and quality (quality defined as the percentage of total flour protein as glutenlike protein). Whereas the variable levels of endogenous α-amylase and protease activities in the triticate flours were expected to affect bread quality, these effects were not readily discernible under the conditions of the straight-dough bake test used in this study.

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**LITERATURE CITED**


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