Factors Affecting the Breadmaking Potential of Four Secondary Hexaploid Triticales[1]

L. J. MACRI,[2] G. M. BALLANCE, and E. N. LARTER

ABSTRACT

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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 triticale flours varied widely, and all triticale flours had higher levels of α-amylase and exoprotease activity, similar levels of endoprotease activity, and lower gluten protein contents than the wheat flours. Triticale 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 triticale samples, only 4T triticale flour produced bread with a sticky crumb.

Hexaploid triticale (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, Lorenz et al 1972, Tsen et al 1973). Past research indicates that the poor baking performance of triticale 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 triticale × bread wheat crosses) that show stronger mixing characteristics than earlier developed varieties and produce acceptable bread from 100% triticale 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 triticale 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 dockage tester (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 Buhler 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-gram samples were ground for 20 sec on a Strong Scott 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 macroKjeldahl method of Williams (1973) using a TiO_2 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 triticale 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 shriveled at maturity in both 1983 and 1984. Kernel shriveling in triticale 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 triticale 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

[1]Contribution no. 728 of the Department of Plant Science, University of Manitoba, Winnipeg, Canada R3T 2N2.

[2]Present address: Canadian Grain Commission, Grain Research Laboratory, 1404-303 Main St., Winnipeg, Manitoba, Canada R3C 3G8.

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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 glutens 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 glutens 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 glutelin) 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 dried glutens 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 II) 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) activity 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)

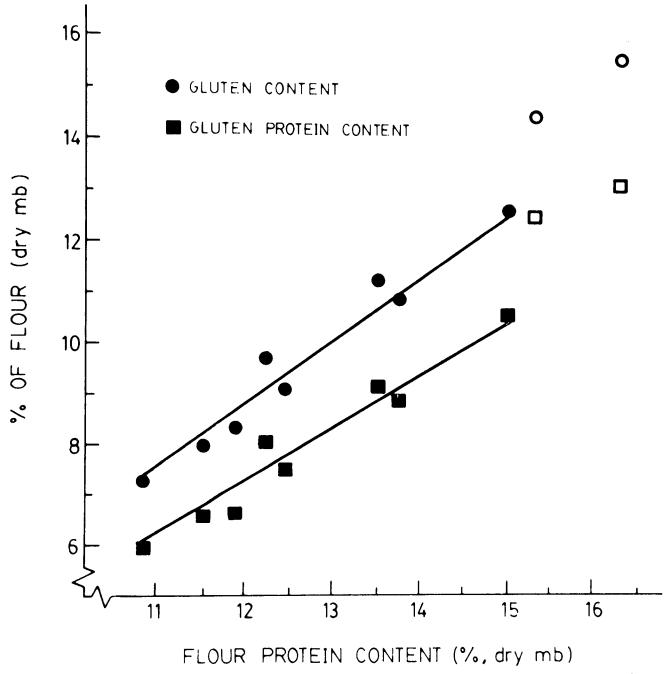

Fig. 1. The relationship between the amounts of dry gluten, gluten protein, and total protein (N × 5.7) in the triticale flours. Open symbols (O, □) represent data for the Marquis wheat flours.

TABLE I
Whole Grain Characteristics[a]

Characteristic	Year	Triticale 4T	Carman	11T	Impala	Wheat (Marquis)
Test weight (kg/hl)[b]	1983	72.2 c	65.5 b	72.3 c	60.3 a	74.0 d
	1984	73.9 d	65.5 b	72.1 c	62.0 a	79.7 e
1,000-kernel weight[c] (g)	1983	40.1 d	41.3 e	38.1 c	36.1 b	27.5 a
	1984	40.8 d	40.3 d	37.0 c	35.1 b	32.3 a
% Protein (N × 5.7)[c]	1983	11.4 a	12.6 b	13.3 c	14.4 d	14.8 e
	1984	10.9 a	12.0 b	12.5 c	13.2 d	14.0 e
Falling number (sec)[b]	1983	69 a	86 b	147 c	65 a	371 d
	1984	62 a	160 c	98 b	65 a	376 d
Kernel hardness (PRI)[d] (g)	1983	11.6 c	10.0 b	10.0 b	8.1 a	12.4 d
	1984	11.4 c	8.7 b	8.0 a	8.6 b	11.5 c

[a] 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.
[b] As is mb.
[c] 14% mb.
[d] PRI = pearling resistance index.

TABLE II
Flour Composition and Baking Quality Characteristics

Characteristic	Year	Triticale 4T	Carman	11T	Impala	Wheat (Marquis)
Flour yield (%)	1983	68.0	64.7	67.9	58.2	71.1
	1984	67.6	63.7	68.7	59.0	72.3
Damaged starch[a]	1983	24	14	16	11	17
(Farrand units)	1984	23	14	14	10	17
% Protein (N × 5.7)[a,b,c]	1983	10.2 a	10.7 b	11.8 c	12.9 d	14.0 e
	1984	9.3 a	9.9 b	10.5 c	11.6 d	13.2 e
Zeleny sedimentation (cm^3)[b,c]	1983	26 a	29 a	26 a	40 b	58 c
	1984	25 a	25 a	30 b	39 c	59 d
Farinograph absorption (%)	1983	58.3	59.9	56.7	57.1	61.1
	1984	56.3	56.4	53.9	54.2	60.8
% Ash[a,b,c]	1983	0.46 b	0.56 c	0.43 a	0.56 c	0.46 b
	1984	0.41 a	0.51 d	0.47 c	0.57 e	0.43 b
Loaf volume (cm^3)[c,d]	1983	365 a	438 b	468 b,c	497 c	630 d
	1984	323 a	407 b	492 c	480 c	600 d

[a] 14% mb.
[b] Average of duplicates.
[c] Within each row, means followed by the same letter are not significantly different ($P = 0.05$) by Duncan's multiple range test.
[d] Average of triplicates (three bakes, one loaf each).

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.

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

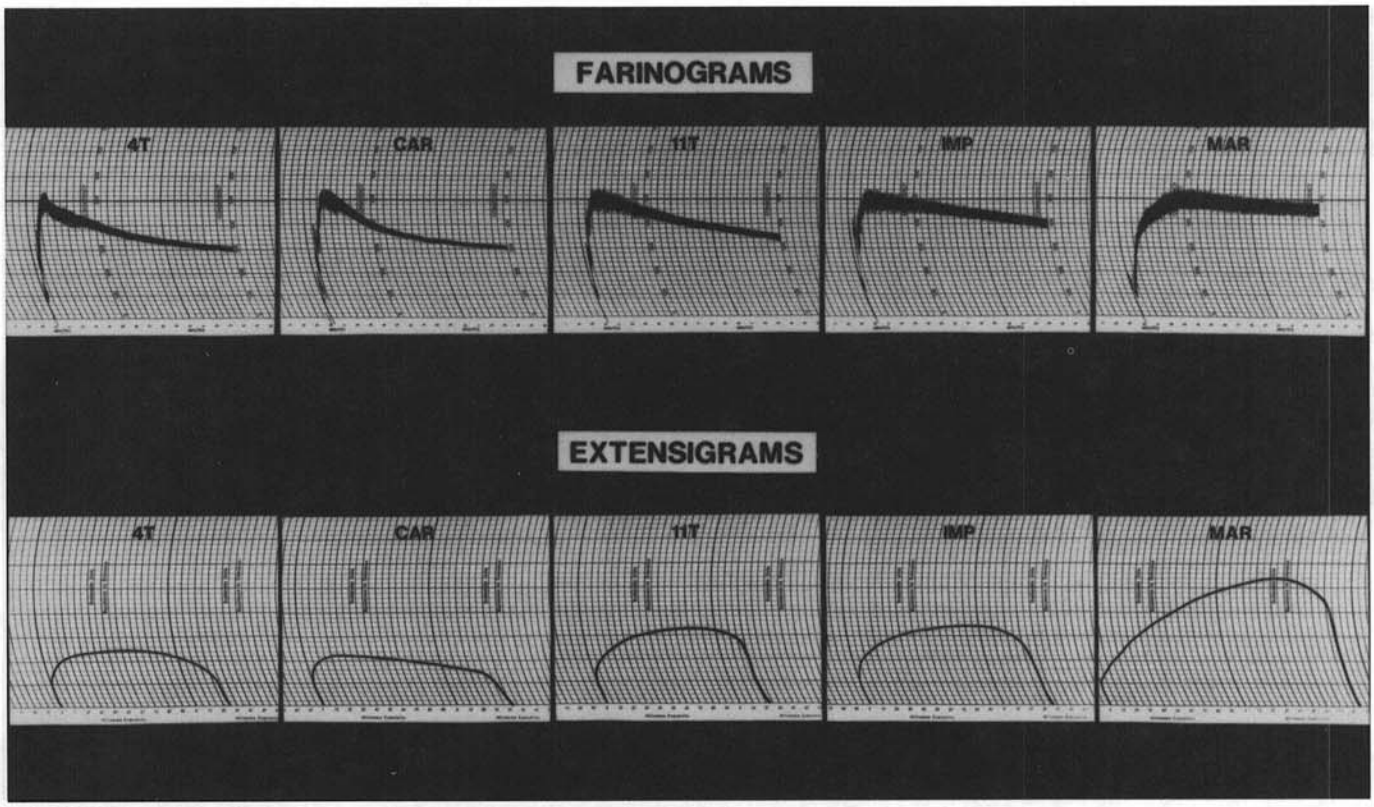

Fig. 2. Farinograms and extensigrams (135-min stretch) of the 1984 samples.

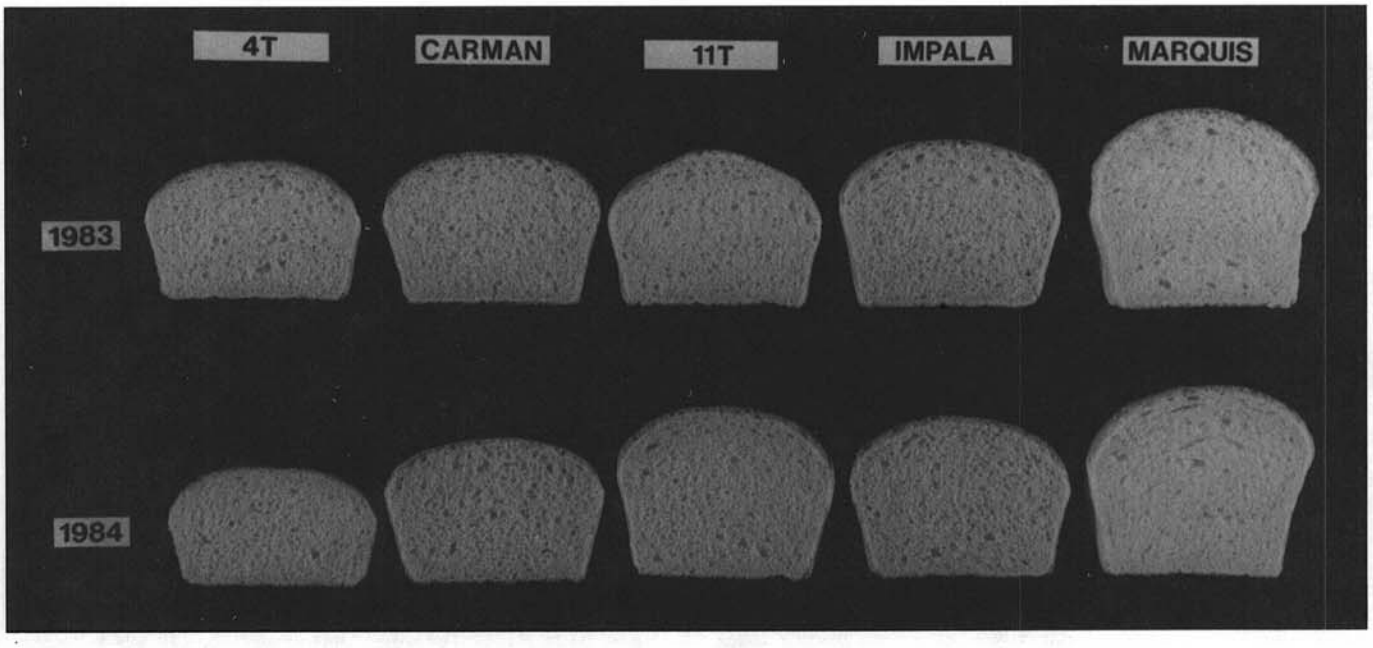

Fig. 3. Internal loaf characteristics of the straight-dough breads.

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 triticale breads even though α-amylase activity varied widely among the triticale 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 triticale 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 triticale 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 triticale 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 triticale 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 triticale breads varied widely in 1984 (Table II) even though there was no significant difference in endoprotease activity among the 1984 triticale 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, triticale 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 triticale can be altered enzymatically during grain maturation is worthy of further investigation.

TABLE III
Flour Enzyme Activities[a]

Activity	Year	Triticale 4T	Triticale Carman	Triticale 11T	Triticale Impala	Wheat (Marquis)
Alpha amylase (GAA[b] units/ g dry flour)	1983	12.7 d (53)	5.4 c (43)	2.9 b (63)	15.8 e (41)	0.2 a (29)
	1984	41.1 d (68)	3.0 b (49)	3.2 b (47)	29.1 c (60)	0.2 a (57)
Exoprotease (μg glu/ g dry flour/hr)	1983	242 b (32)	308 c (35)	244 b (34)	494 d (48)	197 a (36)
	1984	271 b (35)	316 c (32)	325 c (38)	588 d (47)	212 a (33)
Endoprotease (ΔOD_{440}/ g dry flour/hr)	1983	0.017 a (47)	0.036 b (78)	0.015 a (45)	0.032 b (88)	0.017 a (85)
	1984	0.034 a (57)	0.032 a (43)	0.033 a (48)	0.035 a (56)	0.021 a (54)

[a] 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. Values in brackets represent (flour activity/whole grain activity) × 100.
[b] GAA = Grain Amylase Analyzer.

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 triticale samples increased directly with flour protein content. The inferior baking performance of the triticale 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 triticale 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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