INVESTIGATIONS ON SYNTHETIC CEREAL SPECIES. MILLING, BAKING, AND SOME COMPOSITIONAL CHARACTERISTICS OF SOME "TRITICALE" AND PARENTAL SPECIES[1]

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ABSTRACT

Combination of the rye and durum wheat genomes gives rise to a synthetic species (hexaploid Triticale), the seed of which shows the influence of the two parental genomes. Flour yields of Triticale varieties were intermediate. In some cases, yellow pigment content was as high as that found in durum. Protein content of Triticale was generally rather high, and appears to reflect the influence of the rye genome. The protein quality with respect to baking potential was very low. As much as 40 to 50% of the Triticale flour could be blended with a strong flour such as that obtained from Pembina, a hard red spring wheat, and reasonable loaf volumes could still be obtained. Combination of the rye genome with that of the common bread wheat genome (*Triticum aestivum* syn. *T. vulgare*) gives rise to octaploid Triticale. This synthetic species showed the influence of the *T. aestivum* genome in that a flour with better baking quality was obtained. The high protein content of the octaploid Triticale can be attributed to the influence of the rye genome. The vitreous texture and morphological appearance of the seed indicated the stronger influence of the *T. aestivum* genome in these particular characteristics.

The general milling characteristics of the common spring, winter, and durum wheats have been investigated thoroughly under varying conditions. More recently, considerable interest has been directed toward the study of some new cereal species, synthesized by combination of the genomes of *Triticum* and *Secale*; hence their coined name, "Triticale." O'Mara (1) reports that as early as 1877 Wilson successfully crossed *Triticum* with *Secale*, but it was not until more than a decade later, 1888, that Rimpau reported the successful production of the first Triticale amphidiploid or "new species." Following this early success and until the last decade, attempts to develop Triticale as a new grain crop were confined to the octaploid level. The octaploid Triticales are obtained by combining the six genomes of common bread wheat (hexaploid) with the two genomes of rye (diploid), resulting in a species with eight genomes; hence the term *octaploid*.

Muntzing of Sweden is recognized as the leading scientist in efforts concerned with the octaploids. His progress was summarized (2) for participants in the International Genetics Symposia, 1956, Tokyo and

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Kyoto, Japan. In the last decade, Sanchez-Monge (3) of Spain initiated investigations on the development and improvement of hexaploid Triticale, on the hypothesis that the hexaploid rather than the octaploid is the optimum polyploid level. In the same decade, work on development and improvement of the hexaploid Triticale was initiated and subsequently intensified in the Department of Plant Science, University of Manitoba. This was prompted to a considerable degree by preliminary observations which suggested that under local climatic conditions the hexaploid "as a potential cereal crop has all the appearances of being a considerably more productive starch factory than the best of the present-day bread wheats" (4). A recent report (5) indicates that in animal feed rations, the nutritive value of Triticale appears to be comparable to that of hard red spring wheat. The successful synthesis of these cereal species by genome addition has added new dimensions to investigations concerned with chromosomal direction of biogenesis.

This paper is concerned with results related to milling and baking performance and some general analytical results for a number of hexaploid and octaploid Triticale species. Since the hexaploid Triticales are obtained by an additive combination of tetraploid wheat *(Triticum durum, T. persicum, T. polonicum, T. turgidum*) and diploid rye, these parent species have therefore been included in the study for comparison. The fact that hexaploid bread wheat (*T. aestivum* syn. *T. vulgare*) is one of the components of the octaploid Triticale prompted the inclusion of two common bread wheat varieties. The synthesized hexaploid bread wheat species (6A49) was included for further interest.

Materials and Methods

Grain samples of 15 hexaploid and two octaploid Triticales, four tetraploid *Triticum* species, two varieties of hard red spring wheats, a synthesized bread wheat, two varieties of durum wheat, and one rye variety were milled in a Buhler laboratory mill. The moisture contents of the grain samples were adjusted in the usual manner to a level at which optimum average flour yields could be obtained. The effect of moisture conditioning on milling of the Triticale species was investigated by milling various grain samples at three different moisture levels. Because of the ryelike character of the hexaploid Triticale (6A series), the bran and shorts were passed through the mill stream a second time to obtain a higher extraction.

Crude protein was determined by the Kjeldahl procedure in the conventional manner (6). Flour color was measured with a Kent-Jones color meter. Yellow pigment in the flour was extracted according to a standard procedure (7), and the quantity related to beta-carotene by reference to a standard curve. Bushel weights and 1,000-kernel weights were determined.

Farinograms were obtained for the individual flours and flour blends by the standard procedure (7). In baking trials, the standard pup loaves (100 g. flour) were prepared by the remix method (8) and the standard AACC method (7). A standard formula (7) was used throughout the baking trials so that under these particular conditions the results would be comparable. For baking tests, flours from a series of hexaploid Triticale species (6A190, 6A20, 6A66, 6A67) were mixed. To obtain sufficient flour for preliminary baking tests, flour from the two octaploid Triticales (8A112 and 8A125) was pooled. Similarly, flour from the tetraploid *Triticum* species (4B) was pooled, although, as can be seen from the farinograms, some variation in dough strength was evident within these two classes.

Results and Discussion

A generic description of the varieties used in this investigation is given in Table I. The hexaploid Triticale varieties had a somewhat papery bran. Seed of the octaploid Triticale species (8A varieties) was similar in vitreousness to that of the bread wheat parent. Varieties with kernel type similar to that of rye generally gave somewhat lower flour

TABLE I

GENERIC IDENTIFICATION KEY

PLOIDY	DESIGNATION	BOTANICAL DESCRIPTION
Tetraploid	4B113	*Triticum turgidum* var. *ramoso-megalopolitanum*
Tetraploid	4B121	*T. turgidum* var. *plinianum*
Tetraploid	4B249	*T. polonicum* var. *levissimum*
Tetraploid	4B276	*T. persicum* var. *stramineum*
Tetraploid	Ramsey (durum wheat)	*T. durum* var. *hordeiforme*
Tetraploid	Stewart (durum wheat)	*T. durum* var. *hordeiforme*
Tetraploid	Fourex (rye)	*Secale cereale* (induced tetraploid)
Hexaploid	Pembina (bread wheat)	*T. aestivum* var. *lutescens*
Hexaploid	Selkirk (bread wheat)	*T. aestivum* var. *lutescens*
Hexaploid	6A49 (bread wheat)	*T. aestivum* (synthesized from *T. turgidum* var. *nigro-baratum* × *Ae. squarrosa*)
Hexaploid	6A20.1 (Triticale)	*T. durum* "Carleton" — *S. cereale*
Hexaploid	6A66.1 (Triticale)	*T. dicoccoides* — *S. cereale*
Hexaploid	6A67.1 (Triticale)	*T. persicum* — *S. cereale*
Octaploid	8A112 (Triticale)	*T. aestivum* — *S. cereale* (awnless)
Octaploid	8A125 (Triticale)	*T. aestivum* — *S. cereale*

TABLE II

KERNEL CHARACTERISTICS, FLOUR YIELD, AND COMPOSITION

VARIETY	BUSHEL WT.	1000-KERNEL WT.	CRUDE PROT. OF SEED	FLOUR YIELD	FLOUR PROTEIN	FLOUR COLOR	YELLOW PIGMENT
	lb.	*g.*	*% DW*	*%*	*% DW*	*K-J units*	*p.p.m.*
Ramsey[a]	66.4	43.7	16.5	74.1	15.7	4.4	4.2
Stewart[a]	66.2	51.8	16.0	72.3	14.4	4.1	3.9
4B113	62.2	44.3	15.0	63.3	14.2	4.9	3.6
4B121	62.5	44.6	15.0	67.1	14.1	3.2	4.3
4B249	61.4	67.2	18.3	71.8	17.1	6.1	2.3
4B276	64.8	29.3	17.9	63.1	15.5	6.0	2.0
Pembina[b]	63.2	29.7	17.2	69.6	16.2	2.6	2.4
Selkirk[b]	62.5	36.9	17.1	71.9	16.3	2.7	2.0
6A49	61.6	44.6	18.0	65.6	17.2	3.9	4.4
Fourex	55.0	36.9	19.1	59.7	13.6	11.1	2.4
6A20.1	48.8	46.3	19.8	63.7	18.8	7.3	3.4
6A20.2	48.0	44.0	19.5	63.0	17.3	7.9	4.0
6A66.1	48.6	45.6	19.3	62.7	17.1	7.0	3.9
6A67.1	53.2	43.6	17.3	60.4	15.1	5.6	1.4
6A67.2	53.0	42.5	17.1	63.4	15.3	5.9	1.4
6A67.3	52.8	41.8	17.3	61.5	16.2	5.5	1.1
6A67.4	52.6	44.1	17.2	64.9	15.3	5.5	1.1
6A67.5	52.4	43.7	16.9	66.7	15.3	5.4	1.8
6A67.6	52.2	42.2	17.3	66.8	15.5	5.8	1.5
6A67.7	52.8	43.1	16.6	66.1	15.2	5.0	1.2
6A67.8	52.0	42.4	16.8	66.8	15.2	5.4	1.4
6A67.9	52.8	41.8	17.1	68.8	15.5	5.9	1.5
6A67.10	52.6	42.0	17.3	66.6	15.1	5.1	1.2
6A67.11	52.2	43.4	16.3	63.4	15.1	7.9	3.3
6A67.12	52.4	44.5	18.1	64.5	16.9	8.0	2.9
8A112	57.5	26.1	17.9	64.7	16.6	4.9	1.7
8A125	55.6	38.8	19.2	67.5	18.0	4.8	2.0

[a] Durum.

[b] Sp. wheat.

yields. In no case, however, was the flour yield of the Triticale as low as that obtained for a variety of rye (Table II).

Considering the tetraploid *Triticum* species as a group, flour yield appeared to be directly related to kernel weight. A similar relationship was evident in the two octaploid Triticales. The synthesized hexaploid bread wheat (6A49) had high bushel weight and yielded a reasonable quantity (65–66%) of flour. Within the hexaploid Triticale varieties no definite relationship was apparent between flour yield and kernel weight.

The tetraploid *Triticum* species (4B series), octaploid Triticale (8A series), and the synthesized bread wheat (6A49) showed little tendency for flour to adhere to the bran and had relatively vitreous endosperm; they compared favorably in these aspects with the hard red spring wheat varieties. In contrast, hexaploid Triticales presented considerable difficulty in milling to obtain a bran reasonably free from flour. This feature, in addition to the wrinkled ryelike seed, was at least partly responsible for the generally low flour yield after the first mill run. Only after a rerun of the bran and shorts was the flour yield comparable to that of the tetraploid wheats. Flour yields were maximum when the Triticale grain samples were conditioned to 14.5% moisture (Table III).

TABLE III
EFFECT OF MOISTURE CONDITIONING OF TRITICALE GRAIN SAMPLES ON FLOUR YIELD AND FLOUR COLOR

VARIETY	FLOUR YIELD	FLOUR COLOR	FLOUR YIELD AFTER REMILL OF BRAN AND SHORTS
		K.J. units	
16.5% moisture			
6A67.3	52	5.50	59
6A20.1	54	7.30	61
15.5% moisture			
6A20.2	53	7.85	62
6A66.1	53	7.00	63
8A66.3	53	6.45	62
6A67.1	50	4.60	60
6A67.2	53	4.90	62
6A67.4	55	5.50	64
14.5% moisture			
6A67.7	56	5.00	66
6A67.9	59	5.90	68
6A67.11	53	7.85	64
6A67.8	57	5.35	67
6A67.10	57	5.10	68
6A67.12	55	7.95	65
6A190	57	11.80	67

It appears that high crude protein content (Table II) of the grain was at least to some extent associated with the rye genomes, as was the shriveled kernel characteristic. The Triticale varieties 6A20.1, 6A20.2, and 6A66.1 had somewhat higher crude protein contents (19.8, 19.5, and 19.3%) than rye (19.1%); the 6A67 series (15 varieties) contained 16.4–18.1% with an average of 17.6% protein, which was comparable to the 15.8 and 16.0% found in the two tetraploid durum wheats. The protein content of the two octaploid Triticales 8A112 and 8A125 (17.9 and 19.2% respectively) was somewhat higher than that found in the two hard red spring wheat varieties Pembina and Selkirk (17.2 and 17.1% respectively) and again this may be a reflection of the rye genome. The generally high crude protein content of the various varieties of wheat and Triticale and the rye variety can also be attributed, at least in part, to the rather dry growing season in 1961. The nature of the proteins of some selected varieties of Triticale is being investigated in more detail. Hall (9) has obtained evidence by use of immuno-electrophoretic techniques that the rye-wheat combination (Triticale) apparently contains the protein complements of the parental species. How rigidly this pattern holds will require further study.

The Triticale varieties generally gave flours that were darker than that obtained from the two durum varieties, but considerably lighter than the flour obtained from rye.

With some notable exceptions, the synthetic cereal species contained less yellow pigment than the two durum varieties. There appears to be some association between the Kent-Jones flour color and yellow pigment content. Whether the higher pigment content in a few of the synthetic species can be attributed to their chromosomal constitution is not certain, and speculation on this point is premature.

Details concerning the farinograph curves of the individual flours and flour blends are presented in Table IV and Fig. 1. Doughs

TABLE IV
FARINOGRAPH PROPERTIES OF DOUGHS AND BAKING PERFORMANCE OF SOME SELECTED VARIETIES AND CERTAIN FLOUR BLENDS

VARIETY OR FLOUR BLEND	FARINOGRAM		BAKING ABSORPTION	LOAF VOLUME
	Devel. Time	Absorption		
	min.			*cc.*
Ramsey	1.75	72.8		
Stewart	1.75	74.3		
4B113	2.00	73.0		
4B121	2.25	71.5		
4B249	3.50	76.5		
4B276	2.75	75.3		
Fourex	1.25	61.6		
6A20.1	1.25	64.4		
6A66.1	1.25	66.0		
6A67.1	1.25	62.3		
6A67.4	1.50	65.3		
8A112	2.00	63.5		
8A125	5.50	70.7		
Pembina	8.00	64.6	59.6	804
Selkirk	5.50	66.8	59.8	926
6A49	3.25	64.9	62.0	675
T-10 + P-90[a]	7.25	62.8	58.5	935
T-20 + P-80	5.50	61.9	58.8	995
T-30 + P-70	5.25	62.2	58.6	922
T-40 + P-60	4.50	62.0	56.6	837
T-50 + P-50	3.50	61.8	55.1	679
T-10 + S-90[b]	4.50	64.6	59.3	936
T-20 + S-80	4.50	64.2	59.1	893
T-30 + S-70	3.75	63.9	57.6	793
T-40 + S-60	3.00	62.7	57.1	644
T-50 + S-50	2.50	62.2	56.2	544
8A-80 + P-20[c]	4.00	64.4	60.6	785
4B-90 + P-10[d]	2.75	72.5	67.1	620
4B-80 + P-20	3.25	71.5	67.1	670

[a] T-10 + P-90 = 10% Triticale (hexaploid), 90% Pembina blend.
[b] S = Selkirk.
[c] 8A = octaploid Triticale.
[d] 4B = tetraploid wheat.

obtained from flour from the hexaploid Triticale gave curves very similar to those obtained from durum wheat and rye. The doughs were generally weak, with short development times. Flour protein (Kjeldahl protein) of these synthesized species was generally rather high, indicating that protein quality was inadequate with respect to dough strength. This feature does not necessarily reflect on the nutritional quality of the protein. As stated earlier, investigations (5) indicated that the nutritional quality of the Triticale in poultry rations was comparable to that of hard red spring wheat.

The strength of dough from a synthesized bread wheat (6A49) was considerably greater than that of the hexaploid (6A series) Triticale. Development times of doughs from flour of the tetraploid *Triticum* species (4B113, 4B249, 4B276, 4B121) ranged from 2 to 3.5 min. (compare the synthesized bread wheat's (6A49) development time, 3.25 min.). Of the two octaploid Triticale species, one variety (8A112) gave a rather weak dough (development time 2 min.), whereas 8A125 gave a dough comparable in strength (5.5 min.) to that of Selkirk (5.5 min.). Pissarev and Samsonoff (10) have reported similar results in their investigations concerned with octaploid Triticale. Pembina gave a very strong dough with a development time of at least 8 min. It should be emphasized that the sample of Pembina used in these studies exhibited greater than usual dough strength. As might be expected, considerable proportions of flour from the hexaploid Triticale could be blended with Pembina and reasonable dough strength could still be maintained. Thus 30 to 40% of hexaploid Triticale in Pembina gave a dough development time of about 5 min., which was comparable to that of Selkirk.

Preliminary baking trials using flour from the hexaploid Triticale alone gave unsatisfactory results. It was observed, however, that as much as 40% Triticale could be blended with Pembina and still yield loaf volumes comparable to those obtained when Pembina alone was used. Loaf volume was optimum when 20 to 30% Triticale flour was incorporated (Table IV). It is believed that the protein of Pembina contributed to dough strength to such an extent that maximum loaf expansion during baking was prevented. An increasing quantity of weak but relatively high-protein flour from hexaploid Triticale eventually gave a dough in which gas pressure and strength of protein network were optimum to attain high loaf volumes. Loaf volumes for the tetraploid wheats and octaploid Triticale varieties were generally inferior to those of Selkirk and Pembina. More detailed studies of these classes of species are projected as greater quantities of grain become available. Extrapolation from the farinograph curves indicates

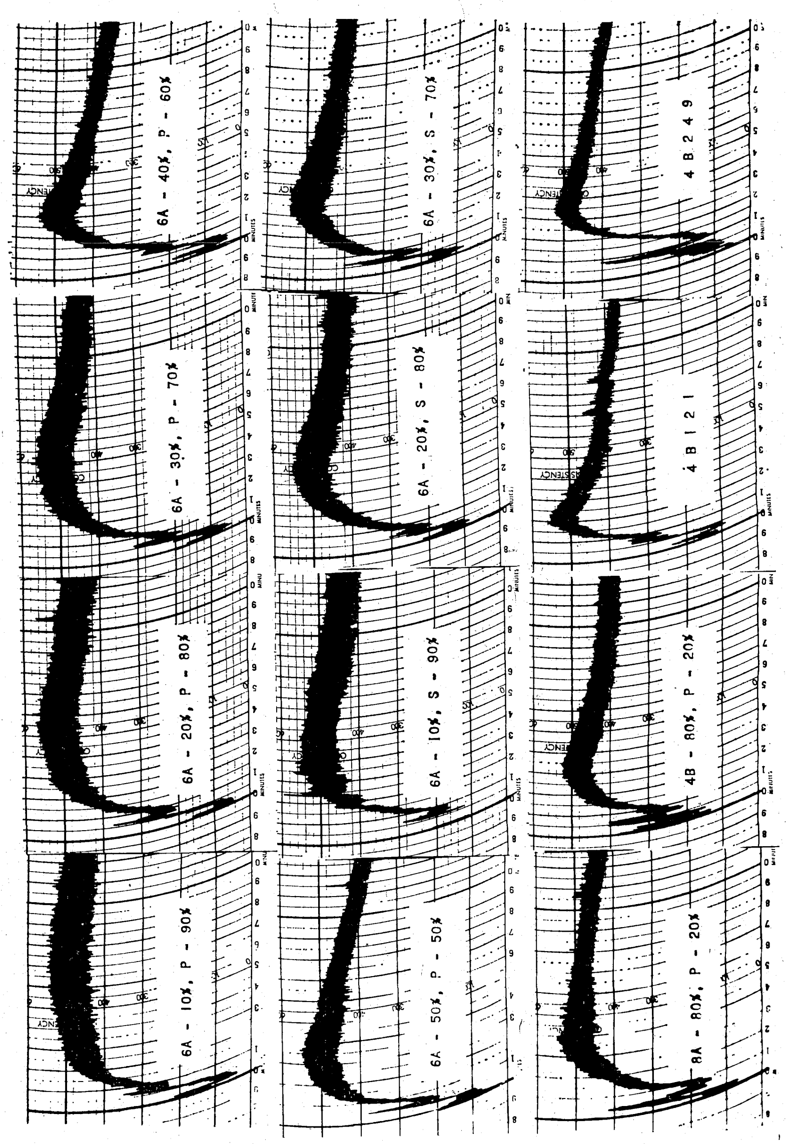
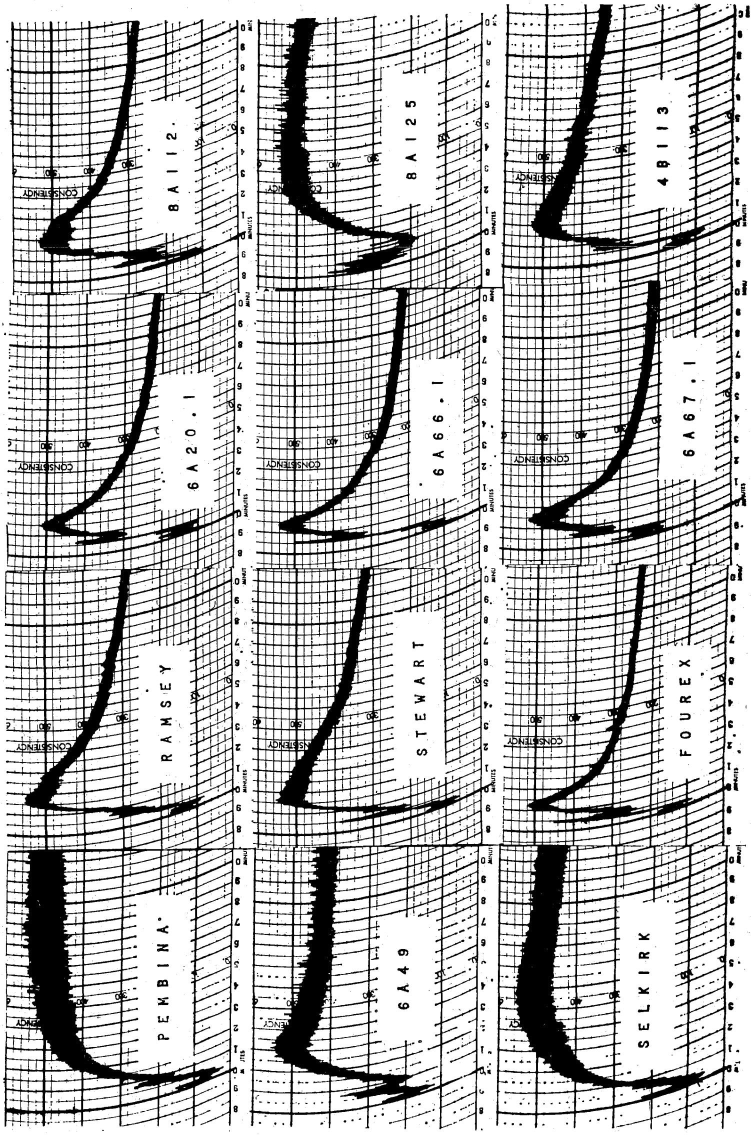


Fig. 1 (this page and opposite). Farinograph curves of some individual flours and flour blends. P, Pembina; S, Selkirk; 6A, hexaploid Triticale; 8A, octaploid Triticale; 4B, tetraploid Triticums.

that at least some of these varieties may give suitable baking results when used alone or when a small proportion of flour of a strong wheat like Pembina is incorporated. A comparison (Table V) of the remix (8) and the AACC methods indicated that the former gave a better evaluation concerning the baking potential of the flour samples. Loaf volumes using the AACC method were generally lower. This was



particularly noticeable with the flour blends at which maximum loaf volumes were observed using the remix procedure. It was also of interest to note that flour milled from Pembina grain which had been stored at 40°F. for approximately 1½ years gave by itself even lower loaf volumes than previously obtained (Table IV). Loaf volume was maximum in these experiments when 30% Triticale flour was blended;

TABLE V

COMPARISON OF BAKING RESULTS USING THE REMIX AND AACC PROCEDURES

VARIETY OR FLOUR BLEND	LOAF VOLUME	
	Remix	AACC
Pembina[a]	635	640
T[b]-10 + P-90	875	690
T-20 + P-80	985	715
T-30 + P-70	995	730
T-40 + P-60	820	725
T-50 + P-50	735	675
Selkirk[c]	925	825
T-10 + S-90	1,000	815
T-20 + S-80	850	810
T-30 + S-70	775	790
T-40 + S-60	705	710

[a] 1961 crop, stored at 40°F., milled shortly before use in December 1963.
[b] 1963 crop.
[c] 1961 crop, stored and handled as described for Pembina.

even at the 50-50 level, loaf volume was still considerably greater (100 cc.) than when Pembina flour alone was used.

Crumb color of the Triticale-Pembina blends was generally somewhat darker than when Pembina or Selkirk alone was used. This may be expected because of the generally darker color of the flour from Triticale. Crumb texture and loaf appearance were reasonably satisfactory when as much as 40% Pembina and 20% Selkirk was blended with flour from the hexaploid Triticale. A more open network was evident in loaves with the greatest volume. Flavor of loaves from the flour blends was judged to be as least comparable if not superior to that obtained from flour of Pembina or Selkirk alone. It is of course realized that flavor is largely a matter of individual preference.

A number of interesting possibilities in biochemical interactions may be proposed for the Triticale species. For example, will the *Secale* and *Triticum* genomes contribute additively to the protein composition? Will the carbohydrate complement be influenced in a similar manner? At this early stage it is assumed that the *Secale* and *Triticum* genomes will maintain their synthetic identity and probably contribute in an additive manner to the biosynthetic machinery. Investigations concerning these problems are under way.

Acknowledgments

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