NOTE ON THE AMINO ACID COMPOSITION OF PROTEIN FRACTIONS FROM A DEVELOPING TRITICALE AND ITS RYE AND DURUM WHEAT PARENTS[1]

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The amino acid composition of cereal grains changes rapidly during kernel maturation (1-5). This reflects a decrease in the nonprotein nitrogen (6-8), buildup of storage protein (2-6), and changes in the compositions of protein fractions as the kernel matures (1-3).

The amino acid compositions of mature triticale flour and its parental species have been determined (9,10). These studies show that the composition of triticale was essentially intermediate between those of the parents.

This report extends previous studies by determining the amino acid composition of one line of hexaploid triticale and its rye and durum wheat parents at different stages of kernel development. In addition to total composition, the compositions of protein fractions at the same stages of kernel development are reported.

MATERIALS

The triticale used in this study was the line 6A190. It is the same line that was used in previous studies from this laboratory (9,10). The rye parent of this triticale is the spring variety Prolific and the durum parent was the variety Stewart. The material used in this study was the same as that in a previous paper (11).

METHODS

Amino acid analyses were performed on a Beckman 121 Automatic Amino Acid Analyzer following the method of Spackmann *et al.* (12) with a precision of ±3%. Samples were hydrolyzed as described by Orth *et al.* (13). Nitrogen recoveries ranged from 80–95%, depending upon the type of sample and the maturity of the grain.

RESULTS AND DISCUSSION

The Amino Acid Composition of the Developing Whole Grain

The amino acid composition of the developing whole grains of triticale 6A190 and of the parents, Prolific rye and Stewart durum wheat, are shown in Table I. Major changes occurred in all three cereals during the first 4 weeks of development. Thereafter, further changes were small. The most noticeable changes were a decrease in the relative proportions of lysine, aspartic acid,

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glycine, and alanine, and an increase in glutamic acid and proline.

Throughout the development process, triticale maintained an amino acid composition that was essentially intermediate between the compositions of the two parents. Although all three cereals had comparable levels of phenylalanine throughout development, that of triticale was slightly lower at each stage of development than in the parents. The accuracy of the methionine determination is quite low because of oxidative degradation of this amino acid during hydrolysis. Accordingly, little significance is attached to the observed methionine results.

The observed changes in amino acid composition during development are generally consistent with the decrease (14) in the proportions of free amino acids and water-soluble proteins and an increase in the proportion of storage protein (14). Changes in composition observed in the present study are, in general, similar to those obtained for other cereal grains (1-5).

Amino Acid Composition of Protein Fractions

The amino acid compositions of the water-soluble protein fraction (albumins) of triticale 6A190 and its parents during development are presented in Table II. The composition of this fraction changed greatly in all three cereals up to the fourth week after anthesis. Among the major common changes were a decrease in lysine, aspartic acid, alanine, and glycine, and an increase in glutamic acid and proline. It is interesting to note that these changes were the same as those observed in the composition of the total grain protein during development (Table I). The amino acid composition of triticale albumin was essentially intermediate to that of its parents at each stage of development examined.

The amino acid compositions of the salt-soluble protein fraction (globulins) of the grains at various stages of development are presented in Table III. Numerous small changes occurred during development in this fraction for all three cereals. These included a decrease in lysine, aspartic acid, threonine, isoleucine, leucine, tyrosine, and phenylalanine, and an increase in histidine, arginine, glutamic acid, and glycine. The globulins from all three cereals were similar, being characterized by a high lysine and arginine content and a very low glutamic acid and proline content compared to the whole grain proteins.

The amino acid compositions of the ethanol-soluble fraction (gliadins) for the three cereals are presented in Table IV. A marked change in the amino acid composition of gliadins from both triticale and rye occurred between the second and third weeks after anthesis. Since only trace amounts of gliadins were present in these two cereals 2 weeks after anthesis (11) there is a possibility that this fraction may have been contaminated by other proteins. Histidine was present in very small amounts 3 weeks after anthesis in rye gliadins but had increased substantially by 5 weeks after anthesis. The gliadins from all three cereals were characterized by a very low lysine content and high glutamic acid and proline contents. Thus, rapid gliadin synthesis during the early stages of development (11) accounts for a large part of the observed changes in amino acid composition of the maturing whole grain (Table I).

The amino acid compositions of the acetic acid-soluble fraction (glutenins) are presented in Table V. The amount of this fraction in triticale 2 weeks after anthesis and in rye 2 to 3 weeks after anthesis was extremely small (11). Thus, contamination may account for the uncharacteristic amino acid compositions

TABLE I
Amino Acid Composition of Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye, and Stewart Durum[a]

(Mol Per Cent on an Ammonia-Free Basis)

Weeks after Anthesis	Triticale					Rye					Durum Wheat				
	2	3	4	5	7	2	3	4	5	7	2	3	4	5	7
Lysine	4.6	3.3	3.1	2.7	2.9	5.4	4.2	3.6	3.1	3.3	3.7	2.7	2.2	2.2	2.2
Histidine	1.9	1.9	1.8	1.9	1.9	1.9	1.8	2.0	1.9	1.9	1.7	1.9	1.9	1.9	1.9
Arginine	3.4	3.3	3.2	3.5	4.1	3.1	3.3	3.5	3.7	3.9	3.2	3.0	3.1	3.4	3.5
Aspartic acid	10.1	6.8	7.3	6.3	6.7	10.6	9.2	6.8	6.3	7.3	7.7	7.0	4.7	4.7	4.7
Threonine	3.8	3.4	3.3	3.2	3.2	4.2	3.8	3.6	3.4	3.5	3.5	3.0	2.9	2.8	2.9
Serine	6.3	4.9	5.8	5.4	5.6	6.1	5.8	5.6	5.7	5.8	6.6	5.5	5.6	5.0	5.7
Glutamic Acid	22.0	26.5	27.9	28.9	27.2	18.1	22.9	25.7	26.7	25.4	24.9	30.4	32.4	33.4	32.3
Proline	7.3	12.1	12.5	13.3	13.1	8.2	11.2	13.1	13.9	13.9	9.8	11.9	13.7	13.8	13.4
Glycine	8.1	7.6	7.3	7.2	7.5	8.7	7.8	7.5	7.3	7.6	8.3	6.8	6.3	6.1	6.5
Alanine	12.6	8.0	6.8	6.2	5.6	13.1	7.4	6.8	6.3	6.1	8.8	6.1	5.2	4.8	4.8
Valine	4.9	5.1	4.8	4.8	5.1	5.6	5.3	5.3	5.2	5.3	5.1	4.6	4.5	4.5	4.6
Methionine	1.1	1.4	1.1	1.3	1.4	0.7	1.3	1.2	1.2	0.9	0.5	1.1	1.1	1.1	0.9
Isoleucine	3.4	3.6	3.4	3.5	3.5	3.7	3.6	3.4	3.3	3.3	3.7	3.7	3.7	3.5	3.6
Leucine	6.3	6.9	6.5	6.6	6.6	6.6	6.9	6.6	6.4	6.5	6.9	6.8	6.9	6.9	7.0
Tyrosine	1.5	1.7	1.7	1.8	1.8	1.0	1.5	1.4	1.6	1.6	2.0	1.8	1.9	1.9	2.0
Phenylalanine	2.8	3.6	3.5	3.6	3.7	3.1	3.9	3.9	3.9	3.9	3.5	3.9	3.9	4.1	4.1

[a]Tryptophan, cysteine, and cystine were not determined.

TABLE II
Amino Acid Composition of the Albumins from Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye and Stewart Durum[a]

(Mol Per Cent on an Ammonia-Free Basis)

	Triticale					Rye					Durum Wheat				
Weeks after Anthesis	2	3	4	5	7	2	3	4	5	7	2	3	4	5	7
Lysine	5.6	4.5	3.8	3.8	3.1	6.0	4.4	3.2	3.0	3.4	5.3	4.7	3.9	4.2	3.8
Histidine	2.0	2.0	1.7	1.8	1.7	2.0	1.8	1.6	1.6	1.7	2.0	2.0	1.9	2.1	1.8
Arginine	3.7	4.1	3.3	3.6	3.4	3.3	3.7	3.0	2.9	3.4	4.1	4.2	3.9	4.4	3.5
Aspartic Acid	9.3	8.7	6.5	6.7	6.3	10.9	7.7	5.5	5.3	6.3	8.8	8.1	7.4	7.1	6.4
Threonine	4.7	4.8	3.8	4.1	4.0	5.0	4.0	3.7	3.6	4.1	4.5	4.4	4.1	4.5	4.2
Serine	6.4	6.2	6.1	6.2	5.4	6.8	5.5	5.6	5.7	5.6	6.5	6.1	6.2	6.3	6.7
Glutamic Acid	16.1	16.1	24.6	22.4	25.4	14.5	20.9	27.1	27.9	25.2	17.1	18.9	22.0	21.5	23.5
Proline	8.6	8.4	13.1	12.9	13.8	7.3	12.7	16.5	15.9	13.7	8.0	8.7	9.9	9.3	11.5
Glycine	8.8	9.0	6.9	7.2	6.8	9.3	7.4	5.6	5.5	6.8	8.4	8.3	7.9	8.4	7.9
Alanine	8.2	8.6	6.5	6.9	6.4	8.9	6.9	5.8	5.7	6.6	8.6	8.5	7.7	8.1	7.4
Valine	6.3	7.2	5.4	5.8	5.4	6.8	5.8	5.0	5.2	5.6	6.7	6.4	6.4	6.0	5.7
Methionine	1.8	2.1	1.4	1.7	1.5	1.7	1.6	1.4	1.5	1.6	1.7	1.9	1.7	1.5	1.6
Isoleucine	3.8	4.0	3.4	3.5	3.5	3.8	3.7	3.3	3.5	3.4	4.1	3.9	3.6	3.5	3.3
Leucine	8.4	8.4	7.0	7.3	6.9	7.7	7.5	6.5	6.6	6.8	8.1	8.0	7.5	7.3	7.0
Tyrosine	2.6	2.9	2.3	2.5	2.4	2.5	2.3	1.9	1.7	1.8	2.7	2.7	2.6	2.6	2.5
Phenylalanine	3.8	3.3	4.2	3.8	4.0	3.6	4.2	4.6	4.5	4.0	3.6	3.5	3.4	3.4	3.1

[a]Tryptophan, cysteine, and cystine were not determined.

TABLE III
Amino Acid Composition of the Globulins from Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye and Stewart Durum[a]

(Mol Per Cent on an Ammonia-Free Basis)

	Triticale					Rye					Durum Wheat				
Weeks after Anthesis	2	3	4	5	7	2	3	4	5	7	2	3	4	5	7
Lysine	6.1	5.6	6.1	5.6	5.6	6.1	6.5	5.5	5.6	5.6	6.8	5.8	5.9	5.3	5.1
Histidine	2.2	2.2	2.1	2.3	2.7	2.4	2.3	2.3	2.6	2.7	2.1	2.6	2.7	2.6	2.7
Arginine	5.8	6.3	7.0	7.3	7.7	5.4	6.5	6.8	7.4	8.1	6.2	7.0	7.9	8.3	8.2
Aspartic Acid	9.5	9.0	8.9	8.7	8.8	10.1	9.4	9.0	8.3	8.7	9.1	8.1	8.4	8.8	7.9
Threonine	5.2	4.8	4.7	4.4	4.4	5.3	5.1	4.7	4.3	4.2	4.9	4.3	4.3	4.4	4.1
Serine	6.2	6.2	6.3	6.4	6.8	6.3	6.0	6.4	6.6	6.6	6.1	6.2	6.2	6.4	6.3
Glutamic Acid	11.2	12.8	13.4	13.5	13.5	10.1	11.7	12.9	13.9	13.8	12.5	16.3	14.9	13.9	16.3
Proline	4.8	5.2	5.2	5.0	4.6	5.2	4.9	5.2	5.3	4.7	5.3	5.9	5.2	4.9	5.2
Glycine	8.9	9.2	9.2	9.8	10.3	9.1	9.7	9.6	9.8	9.7	8.7	9.1	9.3	10.0	10.0
Alanine	8.9	9.2	8.6	9.3	8.7	8.7	8.8	9.2	8.7	8.6	8.7	8.2	8.5	9.1	8.4
Valine	7.1	7.4	7.1	7.1	7.0	7.0	7.1	7.2	7.1	7.1	7.1	6.5	7.0	7.3	7.2
Methionine	2.1	2.0	1.6	1.9	1.5	2.1	1.8	1.8	1.6	1.5	1.8	1.7	1.7	1.4	1.6
Isoleucine	5.0	4.7	4.6	4.2	4.1	4.9	4.7	4.4	4.3	4.1	5.0	4.3	4.1	4.0	3.8
Leucine	9.6	9.0	8.7	8.4	8.2	9.4	8.8	8.5	8.3	8.1	8.9	8.1	7.9	7.9	7.6
Tyrosine	3.2	2.7	2.7	2.6	2.5	3.5	3.1	2.7	2.5	2.6	3.0	2.5	2.5	2.4	2.3
Phenylalanine	4.2	3.8	3.8	3.6	3.7	4.4	3.8	3.8	3.9	3.8	3.8	3.5	3.6	3.5	3.4

[a]Tryptophan, cysteine, and cystine were not determined.

TABLE IV
Amino Acid Composition of the Gliadins from Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye and Stewart Durum[a]

(Mol Per Cent on an Ammonia-Free Basis)

	Triticale					Rye					Durum Wheat				
Weeks after Anthesis	2	3	4	5	7	2	3	4	5	7	2	3	4	5	7
Lysine	2.6	0.7	0.6	0.7	0.6	2.5	0.8	0.7	0.7	0.7	0.9	0.5	0.4	0.5	0.6
Histidine	1.1	1.2	1.4	1.0	1.4	1.0	0.1	0.4	1.0	0.9	1.4	1.5	1.5	1.5	1.7
Arginine	2.0	1.6	1.6	1.6	1.5	2.3	1.3	1.2	1.1	1.1	1.9	1.4	1.6	1.5	1.5
Aspartic Acid	5.6	2.8	2.5	2.7	2.4	5.1	2.4	2.0	2.1	1.9	3.0	2.6	2.5	2.5	2.4
Threonine	3.8	2.4	2.2	2.3	2.1	3.5	2.3	2.2	2.1	2.0	2.1	1.9	1.9	1.9	1.8
Serine	8.1	5.4	5.1	5.3	5.3	6.9	5.5	5.8	5.7	5.7	5.4	4.9	5.1	5.0	4.8
Glutamic Acid	29.1	38.1	39.7	37.9	40.4	29.3	39.7	40.4	39.9	41.2	40.1	42.1	40.9	41.9	42.5
Proline	12.1	18.1	19.2	19.5	18.4	13.4	22.6	22.6	22.6	21.6	15.8	18.3	17.9	18.2	17.9
Glycine	7.5	2.9	2.6	2.8	2.9	7.4	2.8	2.5	2.6	3.2	3.1	2.4	2.7	2.4	2.5
Alanine	6.0	3.0	2.7	2.8	2.7	5.6	2.3	2.3	2.4	2.4	3.2	2.7	2.7	2.6	2.6
Valine	4.1	4.3	3.9	4.2	3.9	4.3	4.2	4.4	4.3	4.2	4.0	3.5	3.7	3.6	3.7
Methionine	0.7	1.1	1.0	1.1	1.1	0.7	1.0	0.8	0.9	0.9	0.9	0.8	1.0	0.9	0.9
Isoleucine	4.2	4.3	4.1	4.2	3.9	4.2	3.2	3.2	3.1	2.7	4.2	4.0	4.0	4.0	3.9
Leucine	7.7	7.3	7.0	7.2	6.9	7.9	6.0	5.7	5.6	5.4	7.1	6.8	6.9	6.9	6.6
Tyrosine	1.8	1.8	1.7	1.6	1.7	1.9	1.1	1.1	1.1	1.5	2.0	2.0	2.1	2.0	1.9
Phenylalanine	3.6	5.0	4.9	5.0	4.7	4.2	4.8	4.8	4.8	4.7	4.8	4.7	5.0	4.7	4.8

[a]Tryptophan, cysteine, and cystine were not determined.

TABLE V
Amino Acid Composition of the Glutenins from Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye and Stewart Durum[a]

Mol Per Cent on an Ammonia-Free Basis

	Triticale					Rye					Durum Wheat				
Weeks after Anthesis	**2**	**3**	**4**	**5**	**7**	**2**	**3**	**4**	**5**	**7**	**2**	**3**	**4**	**5**	**7**
Lysine	4.6	1.2	1.1	1.3	1.6	5.8	3.2	1.6	1.3	1.9	1.4	1.3	1.2	1.0	1.1
Histidine	1.6	1.3	1.3	1.4	1.5	1.4	1.5	1.5	1.2	1.5	1.4	1.4	1.4	1.6	1.5
Arginine	3.5	2.0	1.8	2.1	2.6	3.4	2.6	1.8	1.6	2.3	2.1	1.6	2.4	1.8	2.3
Aspartic Acid	6.3	2.4	2.0	2.4	3.0	7.9	4.5	2.6	2.2	3.3	2.8	1.7	2.5	2.3	2.3
Threonine	4.2	2.8	2.6	2.8	3.0	4.7	3.9	2.8	2.5	2.8	2.4	1.8	2.7	1.9	2.8
Serine	6.5	5.9	5.9	6.3	6.4	7.3	7.0	6.2	5.8	5.9	5.7	5.2	6.6	5.4	6.7
Glutamic Acid	24.9	37.7	37.9	37.2	34.6	20.7	29.6	36.8	37.8	33.7	40.9	44.3	38.9	39.9	37.5
Proline	9.5	16.3	17.0	15.4	14.8	8.1	11.3	17.1	18.8	17.2	14.1	16.9	14.4	16.5	14.6
Glycine	9.3	8.4	9.6	9.1	9.6	11.1	11.4	8.3	7.7	8.2	6.5	4.3	8.4	7.0	8.1
Alanine	6.7	3.2	3.1	3.3	3.9	7.1	6.0	3.4	3.2	4.1	3.2	2.1	3.1	2.8	3.3
Valine	5.1	3.5	3.1	3.4	3.8	4.2	4.1	3.7	4.1	4.4	2.9	2.5	3.1	3.3	3.5
Methionine	0.6	0.8	0.8	1.0	1.0	0.7	0.4	0.8	0.8	0.9	0.6	0.8	0.9	0.9	1.0
Isoleucine	3.9	2.8	2.5	2.7	2.6	4.2	3.1	2.5	2.3	2.4	3.5	3.6	2.8	3.5	3.0
Leucine	7.9	5.8	5.2	5.8	5.7	8.0	6.4	5.4	5.1	5.6	5.5	5.7	5.6	6.2	6.2
Tyrosine	2.2	2.8	3.2	3.0	3.1	1.7	2.3	2.3	2.4	2.5	2.4	2.0	2.8	2.5	2.9
Phenylalanine	3.2	3.2	3.1	3.1	2.9	3.9	2.8	3.2	3.3	3.4	4.6	4.9	3.4	3.4	3.4

[a]Tryptophan, cysteine, and cystine were not determined.

TABLE VI
Amino Acid Composition of the Insoluble Residue Proteins from Developing Whole Grain of Triticale 6A190 and Parents, Prolific Rye and Stewart Durum[a]

(Mol Per Cent on an Ammonia-Free Basis)

	Triticale					Rye					Durum Wheat				
Weeks after Anthesis	2	3	4	5	7	2	3	4	5	7	2	3	4	5	7
Lysine	4.4	2.7	3.3	3.4	4.0	5.3	4.2	3.1	3.8	4.4	3.2	3.0	3.0	2.9	3.0
Histidine	1.8	1.7	1.9	2.1	2.1	1.9	1.7	1.5	2.0	2.1	1.5	1.9	1.8	1.9	2.0
Arginine	3.8	3.2	3.7	4.0	4.3	4.1	3.8	3.4	3.6	4.2	3.5	3.5	3.5	3.7	4.0
Aspartic Acid	6.7	5.1	5.6	6.1	6.9	7.6	7.0	5.6	6.6	7.6	5.4	5.2	5.1	5.3	5.6
Threonine	4.1	3.5	3.7	3.7	4.1	4.5	4.0	3.7	4.0	4.3	3.6	3.6	3.7	3.5	3.6
Serine	6.1	6.3	6.3	6.4	6.9	6.1	5.9	6.2	6.3	6.7	6.5	6.9	6.9	6.6	6.6
Glutamic Acid	21.4	27.7	25.3	24.3	21.2	16.9	21.6	25.5	22.5	18.4	27.9	29.7	27.7	27.3	26.2
Proline	10.8	12.8	10.9	11.0	10.0	9.1	11.3	12.9	11.0	9.9	10.4	9.4	10.9	10.9	10.7
Glycine	9.0	9.1	10.0	9.7	10.0	9.7	9.5	10.1	10.3	10.3	8.2	9.0	9.4	8.9	9.0
Alanine	7.1	5.5	6.2	6.3	6.4	8.4	6.8	6.1	6.8	8.1	5.9	5.7	5.8	5.7	6.0
Valine	5.5	4.9	5.1	5.3	5.7	5.9	5.7	5.3	5.6	6.2	5.2	4.8	5.0	5.1	5.2
Methionine	1.2	1.0	1.1	1.1	0.9	1.2	1.1	1.1	1.0	1.1	1.1	0.8	1.1	1.2	1.2
Isoleucine	4.0	3.5	3.4	3.5	3.6	4.3	3.8	3.1	3.7	3.6	3.9	3.6	3.4	3.5	3.5
Leucine	8.0	7.3	7.2	7.4	7.4	8.6	7.8	6.7	7.3	7.7	7.6	7.5	7.3	7.4	7.5
Tyrosine	2.1	2.2	2.4	2.1	2.4	2.1	2.0	2.1	2.0	1.9	2.2	2.1	1.8	2.4	2.2
Phenylalanine	4.0	3.6	3.7	3.7	4.2	4.3	4.0	3.7	3.9	3.7	3.9	3.5	3.6	3.7	3.8

[a]Tryptophan, cysteine, and cystine were not determined.

obtained for these samples at the early stages of development. From 4 weeks after anthesis to maturity, the amino acid composition of this fraction was similar in all three cereals. The level of glycine and tyrosine was higher in triticale than in either parent during this interval while the level of phenylalanine was lower than in either parent. The other amino acids were generally found in triticale glutenins to be intermediate to that of the parents.

Table VI shows the amino acid compositions of the insoluble residue proteins. Although the content of a number of the amino acids within this fraction changed during development for both triticale and rye, at maturity the amino acid composition did not differ greatly from that found 2 weeks after anthesis. Durum wheat residue proteins had a relatively stable amino acid composition throughout all stages of maturation. For all three cereals the levels of glutamic acid and proline were much lower than that found in glutenins (Table V). This agreed with previous findings from other cereals (2,3,5,15) and supports the hypothesis that the insoluble residue proteins are largely structural proteins rather than storage proteins (11).

The amino acid compositions of the protein fractions from all three cereals changed sufficiently during development to have a significant effect on the amino acid composition of the whole grains. Although the various fractions from the three cereals shared common characteristics in amino acid composition, the composition of durum wheat and rye protein fractions showed significant differences. With a few exceptions, the amino acid composition of the five protein fractions from triticale were generally intermediate to that of the parents at all stages of kernel development. These results support the hypothesis that the genomes of the two parents of triticale function throughout kernel development (11).

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