Amino Acid Composition of Six Grains and Winter Wheat Forage

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ABSTRACT

Amino acid profiles were determined on grain of five cultivars each of winter wheat (*Triticum aestivum* L.) and triticale (*Triticosecale*, Wittmack), on three cultivars of rye (*Secale cereale* L.), and on one each of barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), and soybean (*Glycine max* (L.) Merr.) grown in Georgia during two seasons. Oat grain had the most desirable amino acid composition of all grains tested. Oats excelled in lysine, arginine, valine, leucine, isoleucine, and phenylalanine. Oats were equal to other cereal grains in threonine, methionine, and histidine. Barley did not exceed oats in any of the essential amino acids. Lysine content was lower in high-protein (16.5%) barley, whereas glutamic acid and proline were higher. Triticale and rye grains were higher in lysine than wheat grain. The new triticale cultivar Beagle 82 was higher in lysine, histidine, arginine, aspartic acid, threonine, serine, glycine, alanine, valine, methionine, leucine, isoleucine, tyrosine, and phenylalanine than other triticale cultivars tested. Wheat cultivars were lowest in lysine and low in threonine and valine content. Soybeans were low in methionine and lower than oats in valine content. No seasonal differences were found in amino acid composition of wheat, triticale, and oat cultivars, although crude protein varied from season to season. Succulent wheat forage at the grazing stage was high in most essential amino acids, but was low in glutamic acid and proline and very low in cystine.

Considerable research has been reported on nutritional quality as it relates to amino acids in grain crops grown for food and feed. Studies of dark hard and yellow hard wheat showed that protein content rather than grain texture or type governed amino acid composition (Hubbard et al 1977). In both kernel types, protein content was correlated negatively with lysine, serine, and alanine, and positively with glutamic acid. Dubetz et al (1979) found that added increments of nitrogen to Neepawa wheat caused a decrease in lysine, histidine, arginine, aspartic acid, threonine, glycine, valine, and leucine and an increase in glutamic acid, proline, cystine, methionine, tyrosine, and phenylalanine. Kolderup (1974) reported that in spring wheat glutamic acid, proline, and phenylalanine increased with added nitrogen levels, while lysine and methionine decreased the most, and threonine, valine, and alanine also decreased.

Larter et al (1968) and Sikka et al (1978) reported that triticale usually exceeds wheat in protein content and was superior to wheat in lysine and threonine content. Chen and Bushuk (1970) studied the amino acid composition of triticale and its parent species and concluded that the amino acids of triticale were intermediate between the wheat and rye parents. Lysine content of triticale grain was lower than rye but significantly higher than durum and Manitou spring wheat. Dexter and Dronzek (1975) studied the amino acid composition of protein fractions of a developing triticale cultivar, 6A-190, and its parents, Prolific rye and Stewart durum. The triticale maintained an amino acid balance between that of the two parents. As triticale grains developed, they observed a decrease in the relative proportions of lysine, aspartic acid, glycine, and alanine and an increase in glutamic acid and proline.

Preston and Woodbury (1975) tested the amino acid composition of the various rye protein fractions and found them similar to wheat protein. Eppendorfer (1977a) found that by increasing N on rye, a decrease occurred in lysine, threonine, tryptophan, methionine, and cystine while glutamic acid, phenylalanine, and proline increased. He found that lysine and threonine were the first and second limiting amino acids in rye grain.

Pomeranz et al (1977) showed that an increase in N fertilizer on barley decreased the essential amino acids lysine, threonine, and methionine. Pomeranz et al (1976) tested 113 barley cultivars from the world collection and found a significant positive correlation between lysine and aspartic acid in all types studied. Rhodes and Mathers (1974) found the expected negative correlation between total protein and lysine in barley. The storage protein of barley was hordein, which was high in glutamic acid and proline but deficient in the essential amino acids.

Robbins et al (1971) found that the amino acid composition of oat grain makes it nutritionally superior to other cereals. The limiting amino acids in oats were lysine, threonine, and methionine. Frey (1976) stated that the protein of oat grain has three unique features that cause it to be superior to other grains: it has high biological or nutritional value as demonstrated by animal feeding trials; oat protein can be elevated to high levels by genetic means (ie, plant breeding) without adversely influencing quality; and protein quality does not deteriorate as the protein percentage increases. Eppendorfer (1977a) found that oat protein fractions contained mainly desirable glutelins, whereas rye, wheat, and barley contained prolamine fractions that were deficient in lysine but contained large amounts of the nonessential amino acids, glutamic acid, and prolamine. Zarkadas et al (1982) tested the oat cultivar Oxford from eastern Canada and the cultivar Sentinal from western Canada and found the groats with an excellent balance of essential amino acids limited only in lysine.

Kapoor and Gupta (1977) studied the amino acids in developing Bragg soybean and found the general pattern in amino acid development to be similar to that in cereal grains. The first and second limiting amino acids in soybeans are methionine and tryptophan.

It is important to know the processing quality and nutritional value of grain crops used for food and feed. In recent years, interest has been shown in breeding and developing grain crops with higher protein content and better amino acid balance. The experiments described here were designed to study amino acid content, balance, and distribution in wheat grain and forage, in grain of several cultivars of triticale and rye and single cultivars of barley, oats, and soybeans. Results of such research will aid in planning future grain breeding and testing programs to improve the quality of food and feed grains.

MATERIALS AND METHODS

New and old cultivars were chosen to determine whether the grains differed in amino acid composition from one another and from season to season. Soft red winter wheat cultivars tested were Ga. 1123, Holley, Omega 78, Tifton 2015, and McNair 1003. Triticale cultivars were Fasgro 208, 6TA-571, 6TA-579, 6TA-227, and Beagle 82. Rye cultivars were Weser, Tifton Dwarf, and Tifton 13924 composite. Volbar barley, Coker 227 oats, and GaSoy 17 soybean completed the samples, all of which were grown during the 1976 and 1977 seasons at the Coastal Plain Experiment Station, Tifton, GA. Grain and forage samples were obtained by compositing samples from each of four replications. Forage samples were obtained at the succulent grazing stage when the wheat was well tillered and 10 in. tall.

The soil was a Tifton sandy loam (Plinthic Paleudults) fertilized in the fall at planting time with 560 kg/ha of 5-10-15 granular fertilizer. A total of 68 kg/ha of N was applied: 28 kg/ha at planting time and 40 kg/ha as NH_4NO_3 in mid-February. The soil pH was 6.0.

For amino acid analysis, all duplicate samples were ground in a Wiley mill to pass a 40-mesh screen. Dry weights and nitrogen determinations were according to AOAC methods (1975). Crude protein was obtained by micro-Kjeldahl N $\times$ 6.25. Amino acid analyses were performed on a Beckman model 121 Automatic Analyzer, following the procedure of Moore et al (1958). Tryptophan was not determined. Soybean samples were defatted using AOCS method AC3-44 (1975).

RESULTS AND DISCUSSION

Five cultivars of soft red winter wheat were consistently lower in lysine than cultivars of rye, triticale, barley, oats, and soybean (Tables I, II). Wheat grain was lower in threonine than all other grains tested, especially oats and soybean. Wheat grain also was low in valine content compared to oats, barley, and soybean, but was equal to rye and triticale. Wheat grain had similar amounts of arginine, leucine, isoleucine and phenylalanine as rye, triticale, and barley but less than oats and soybean. The nonessential glutamic acid content was higher in wheat than in other grains.

Wheat forage, when compared to wheat grain, contained more lysine, threonine, methionine, valine, alanine, phenylalanine, leucine, and isoleucine and aspartic acid and about the same amounts of arginine and histidine (Table I). Wheat forage was much lower in the nonessential amino acids glutamic acid and proline and was very low in cystine. Wheat forage was comparable to high-quality Coastal Bermuda grass and compared favorably with ryegrass, red clover, and alfalfa in amino acid composition, as reported by Eppendorfer (1977b). It is probably not generally recognized that wheat forage has such high quality and good balance of amino acids.

TABLE I
Amino Acids[a] in Wheat Grain and Forage Grown at Tifton, GA, 1976–1977

	Ga. 1123 1976	Holley 1976	Holley 1977	Omega 78 1976	T-2015 1977	McNair 1003 1977	McNair 1003 1977 (forage)
Lysine	2.68	2.81	2.79	2.81	2.79	2.95	4.68
Histidine	1.56	1.83	1.74	1.66	1.52	2.11	1.47
NH_3	4.07	4.20	3.81	4.29	4.28	3.76	1.82
Arginine	4.89	5.05	4.88	4.78	4.71	5.01	4.88
Aspartic acid	4.80	5.05	4.85	4.89	4.93	4.94	7.84
Threonine	2.78	2.94	2.85	2.90	2.92	2.93	4.34
Serine	4.75	4.99	4.73	3.87	5.01	4.69	3.95
Glutamic acid	30.78	32.27	29.54	31.67	31.89	29.66	10.88
Proline	9.91	10.56	9.63	10.58	10.32	9.45	5.86
Glycine	3.67	4.09	4.03	3.73	3.98	4.04	4.43
Alanine	3.32	3.42	3.35	3.50	3.48	3.48	6.91
Half cystine	1.48	1.61	1.32	1.49	1.50	1.43	.54
Valine	4.08	4.24	4.08	4.25	4.28	4.22	5.47
Methionine	1.69	1.76	1.77	1.82	1.85	1.86	2.16
Isoleucine	3.53	3.67	3.51	3.65	3.75	3.57	4.33
Leucine	6.52	6.72	6.55	6.81	6.91	6.64	7.52
Tyrosine	3.30	3.36	3.26	3.21	3.32	3.17	3.34
Phenylalanine	4.50	4.74	4.51	4.78	4.84	4.62	5.17
Crude protein (%)[b]	16.68	16.37	16.00	15.38	17.62	14.31	18.62

[a]Grams per 100 g of protein.
[b]N $\times$ 6.25.

TABLE II
Amino Acids[a] in Triticale Cultivars Grown at Tifton, GA, 1976–1977

	Fasgro 208 1976	6TA-571 1976	6TA-571 1977	6TA-227 1976	6TA-579 1976	Beagle 82 1977
Lysine	3.51	3.18	3.27	3.41	3.33	3.63
Histidine	1.57	1.58	1.68	1.73	1.61	1.87
NH_3	3.70	4.13	3.80	3.86	3.56	3.72
Arginine	5.25	5.05	5.03	5.44	5.22	5.62
Aspartic acid	5.83	5.58	5.52	5.71	5.58	6.11
Threonine	3.17	3.15	3.10	3.17	3.07	3.29
Serine	4.52	4.76	4.77	4.62	4.50	4.90
Glutamic acid	24.65	28.21	28.40	25.99	24.28	27.70
Proline	9.02	10.05	10.07	9.06	8.95	9.39
Glycine	4.05	4.00	4.00	4.21	3.99	4.30
Alanine	3.84	3.69	3.73	3.82	3.74	4.08
Half cystine	1.44	1.46	1.42	1.56	1.47	1.41
Valine	4.39	4.34	4.40	4.31	4.18	4.59
Methionine	1.79	1.62	1.82	1.80	1.81	1.87
Isoleucine	3.42	3.56	3.60	3.36	3.31	3.68
Leucine	6.30	6.47	6.53	6.34	6.24	6.75
Tyrosine	2.99	3.10	3.16	3.09	2.98	3.20
Phenylalanine	4.30	4.53	4.57	4.29	4.32	4.69
Crude protein (%)[b]	±15.31	15.80	15.80	13.94	14.63	14.75

[a]Grams per 100 g of protein.
[b]N $\times$ 6.25.

TABLE III
Amino Acids[a] in Rye, Barley, Oats, and Soybeans Grown at Tifton, GA, 1976–1977

	Rye			Barley		Oats		Soybeans	
	Weser	T-Dwf.	T-13924	Volbar	Volbar	Coker 227	Coker 227	GaSoy 17	GaSoy 17 defatted
	1976	1976	1976	1976	1977	1976	1977	1977	1977
Lysine	3.52	3.56	3.52	3.62	4.00	4.02	4.14	6.96	6.85
Histidine	1.77	1.65	1.71	1.68	1.76	1.73	1.72	2.29	2.09
NH_3	3.72	3.57	3.48	3.35	2.72	3.17	3.15	2.42	2.24
Arginine	5.31	5.32	5.21	5.15	5.49	6.94	6.95	7.81	7.78
Aspartic acid	6.70	6.48	6.49	5.77	6.74	7.89	8.06	11.38	11.20
Threonine	3.28	3.11	3.12	3.46	3.48	3.53	3.65	4.32	4.17
Serine	4.59	4.40	4.43	4.37	4.31	4.90	4.95	5.51	5.46
Glutamic acid	27.10	24.19	24.65	23.95	21.42	21.14	21.82	19.53	18.68
Proline	11.06	9.93	10.37	10.73	9.46	5.07	5.36	5.22	5.00
Glycine	4.06	3.66	3.95	4.04	4.18	4.61	4.69	4.55	4.52
Alanine	3.89	3.84	3.78	3.84	4.09	4.63	4.72	4.57	4.49
Half cystine	1.30	1.26	1.21	1.28	1.21	1.80	1.83	1.25	1.18
Valine	4.50	4.29	4.30	4.65	4.75	5.28	5.44	5.04	4.91
Methionine	1.86	1.72	1.78	1.70	1.70	1.82	1.83	1.78	1.78
Isoleucine	3.59	32.9	3.40	3.51	3.49	4.01	4.09	4.98	4.87
Leucine	6.34	5.91	6.06	6.91	6.82	7.51	7.69	8.05	7.91
Tyrosine	2.76	2.66	2.63	3.37	3.28	3.73	3.76	4.13	4.08
Phenylalanine	4.92	4.43	4.70	5.19	4.74	5.48	5.56	5.48	5.38
Crude protein (%)[b]	16.38	14.25	15.75	16.50	12.00	16.00	14.19	38.31	45.56

[a] Grams per 100 g of protein.
[b] N × 6.25.

Triticale cultivars were equal to barley in all essential amino acids (Tables II and III). Triticale grain was lower in lysine than barley or rye but was higher in lysine than all five wheats (Table I). Triticale cultivars also were higher in threonine and lower in glutamic acid than wheat cultivars. Amino acid composition of Beagle 82 triticale in these experiments was similar to that of Fasgro 204 and of Fasgro 385 in tests reported by Stringfellow et al (1976). The new triticale cultivar Beagle 82 was higher in lysine, histidine, arginine, valine, methionine, leucine, isoleucine, tyrosine, and phenylalanine than the other triticale cultivars tested. Breeding can improve the amino acid balance and quality in grain, and Beagle 82 triticale is a good example of such improvement. When cultivar 6TA-571, grown in 1976, was compared with the same cultivar grown in 1977, no differences were detected in amino acid composition attributable to seasons.

There was a tendency for rye and triticale grain to contain less leucine than other grains. Otherwise, rye grain contained approximately the same amounts of essential amino acids as barley and triticale. Rye grain contained more lysine than wheat and less glutamic acid. No significant differences were detected in the amino acid composition of the three rye cultivars tested (Table II).

In Georgia tests, Volbar barley did not exceed Coker 227 oats in any of the essential amino acids (Table II). There was a tendency for barley grain to be lower in methionine than other grains. Although a wide difference existed in total protein (16.5–12.0%) between 1976 and 1977, the amino acid content of Volbar barley grain was about the same, with a few exceptions. Lysine content was lower in the high-protein barley, while the glutamic acid and proline contents were higher.

Breeding work to produce Coker 227 oats increased the protein content and crown-rust resistance from genes obtained from *Avena sterilis*. Coker 227 oats produced the highest amounts and the best balance of essential amino acids of any of the grain cultivars tested (Table II). Oat groats excelled in lysine, valine, arginine, leucine, isoleucine, and phenylalanine. They were equal to other cereal grains in methionine, threonine, and histidine. Oats and soybeans were lower in proline than other grains, but oats were equal to soybeans in methionine content. When Coker 227 oats were compared to oats analyzed by Eppendorfer (1977a), Coker 227 oats were found to be slightly lower in histidine, alanine, proline and glycine, but higher in glutamic acid, isoleucine, and phenylalanine and the same in all other amino acids. Comparison with oats tested by Zarkadas et al (1982) showed a higher methionine content in the oat groats from Canada than from Coker 227 produced in Georgia. Amino acid composition of Coker 227 varied little according to seasons, although a two-percentage point difference existed in their crude protein content.

GaSoy 17 soybean was higher in lysine, threonine, arginine, histidine, leucine, and isoleucine content than the cereal grains (Table II). Soybean grain was similar to the cereal grains in low methionine content. The main nutritive value of soybean is its high content of lysine. Defatting of soybean grain had little or no influence on the amino acid composition.

Results of these tests confirm that oat groats have the best balance of essential amino acids and are nutritionally superior to other cereal grains for food and feed. Several plant breeders in the southeastern states have programs for developing, testing, and releasing cultivars of hulless oats. There are obvious advantages of hulless oats if they can be developed and used for food and feed. Test results with triticale cultivars show the possibility of increasing lysine content by breeding and selection. Beagle 82 triticale has higher lysine content and better balance of essential amino acids than any of the triticale or rye cultivars in these experiments. Additional research will undoubtedly improve upon the nutritional value of new triticale cultivars. Many programs are in progress to increase the lysine content of barley, wheat, corn, sorghum, and other crops. In light of this research, improvement in the amount and balance of essential amino acids of grain seems feasible and valuable for the future.

LITERATURE CITED

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analysis. 12th ed. The Association, Washington, DC.

AMERICAN OIL CHEMISTS' SOCIETY. 1974. Official and Tentative Methods. Method AC3-44. The Society, Champaign, IL.

CHEN, C. H., and BUSHUK, W. 1970. Nature of protein in triticale and its parental species. I. Solubility characteristics and amino acid composition of endosperm proteins. Can. J. Plant Sci. 50:9.

DEXTER, J. E., and DRONZEK, B. L. 1975. Note on the amino acid composition of protein fractions from a developing triticale and its rye and durum wheat parents. Cereal Chem. 52:587.

DUBETZ, S., GARDINER, E. E., FLYNN, D., and De La ROCHE, A. I. 1979. Effect of nitrogen fertilizer on nitrogen fractions and amino acid composition of spring wheat. Can. J. Plant Sci. 59:299.

EPPENDORFER, W. H. 1977a. Nutritive value of oat and rye grain protein as influenced by nitrogen and amino acid composition. J. Sci.

Food Agric. 28:152.
EPPENDORFER, W. H. 1977b. Amino acid composition and nutritive value of Italian ryegrass, red clover and lucerne as influenced by application and content of nitrogen. J. Sci. Food Agric. 28:607.
FREY, K. J. 1976. Cereal proteins—Quantity and quality. Iowa Journal paper no. J-8379, Ames. Presented at Maryland Nutrition Conference, March 18–19, 1976, Washington, DC.
HUBBARD, J. D., POMERANZ, Y., and LAI, F. S. 1977. Note on protein contents and amino acid composition of dark hard and yellow hard kernels separated from red winter wheat. Cereal Chem. 45:778.
KAPOOR, A. C., and GUPTA, Y. P. 1977. Changes in proteins and amino acids in developing soybean seed and effect of phosphorus nutrition. J. Sci. Food Agric. 28:113.
KOLDERUP, F. 1974. Effect of nitrate, sulfate, and time of fertilizer application of protein production in wheat. Sci. Rep. Agric. Univ. Norw. 53:1.
LARTER, E. N., TSUCHIYA, T., and EVANS, L. 1968. Breeding and cytology of triticale. Page 213 in: Proc. Int. Wheat Genet. Symp. 3rd.
MOORE, S. D., SPACKMAN, H., and STEIN, W. H. 1958. Chromatography of amino acids on sulfonated polystyrene resins; An improved system. Anal. Chem. 30:1185.
POMERANZ, Y., ROBBINS, G. S., SMITH, R. T., CRADDOCK, J. C., GILBERTSON, J. T., and MOSEMAN, J. G. 1976. Protein content and amino acid composition of barleys from the world collection. Cereal Chem. 53(4):497.
POMERANZ, Y., ROBBINS, G. S., GILBERTSON, J. T., and BOOTH, G. D. 1977. Effects of nitrogen fertilization on lysine, threonine and methionine of hulled and hulless barley cultivars. Cereal Chem. 54:1034.
PRESTON, K. R., and WOODBURY, W. 1975. Amino acid composition and subunit structure of rye gliadin protein fractionated by gel filtration. Cereal Chem. 52(5):719.
RHODES, A. P., and MATHERS, J. C. 1974. Varietal differences in the amino acid content of barley grain during development and under varying nitrogen supply. J. Sci. Food Agric. 25:963.
ROBBINS, G. S., POMERANZ, Y., and BRIGGLE, L. W. 1971. Amino acid composition of oat groats. J. Agric. Food Chem. 19:536.
SIKKA, K. C., DUGGAL, S. K., SINGH, R., GUPTA, D. P., and JOSHI, M. G. 1978. Comparative nutritive value and amino acid content of triticale, wheat and rye. J. Agric. Food Chem. 26(4):788.
STRINGFELLOW, A. C., WALL, J. S., DONALDSON, G. L., and ANDERSON, R. A. 1976. Protein and amino acid composition of dry-milled and air-classified fractions of triticale grain. Cereal Chem. 53(1):51.
ZARKADAS, C. G., HULAN, H. W., and PROUDFOOT, F. G. 1982. A comparison of the amino acid composition of two commercial oat groats. Cereal Chem. 59(5):323.

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