PROTEIN CONTENT AND AMINO ACID COMPOSITION OF MATURING BUCKWHEAT (*FAGOPYRUM ESCULENTUM* MOENCH)[1,2]

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ABSTRACT

Kernel weight, hull:groat ratio, protein content, and amino acid composition were determined in two buckwheat cultivars harvested at four stages of maturity in 1971 and 1973. During maturation, a 3.0- to 5.6-fold increase in whole kernel weight was due to an up to eighteenfold increase in weight of the groat and correspondingly smaller (less than twofold) increase in hull weight. In the groat, the large increase in weight was accompanied by a decrease in protein concentration. In the hulls, concentrations of total nitrogenous compounds decreased considerably during maturation. In the hull proteins, the main changes in amino acids were increases in histidine and glycine. In the groat, contents of arginine increased and lysine, proline, alanine, and isoleucine decreased. Amino acid composition changes markedly in maturing cereals (*e.g.*, wheat, barley, and oats), and legumes (*e.g.*, peas), but is remarkably stable in maturing buckwheat. For limiting amino acids (*e.g.*, lysine) and amino acids of storage proteins (*e.g.*, glutamic acid), changes in buckwheat are intermediate between those of true cereals and legumes.

Feeding experiments of Sure (1) showed that among known plants, buckwheat (*Fagopyrum esculentum* Moench) is one of the best sources of high-biological value proteins. Recently, crude protein and 17 amino acids were determined in 10 samples of genetically diverse buckwheats, in buckwheat fractions from a commercial mill, and in germ and degermed groats (2). The buckwheat proteins were particularly rich in lysine and contained less glutamic acid than cereal proteins. Glutamic acid, basically a nonessential amino acid, is the main component of storage proteins in cereals. Lysine is the nutritionally-limiting amino acid of commercially grown cereal species and cultivars. Consequently, buckwheat proteins are excellent supplements to cereal proteins.

Significant increases in concentrations of glutamic acid and decreases in concentration of lysine during maturation of the seeds of wheat, barley, and oats have been reported (3,4,5). Those crops are true cereals, they have a determinate growth habit, and the grain is classified as a caryopsis. Buckwheat is not a true cereal (Polygonaceae family), it has an indeterminate growth habit, and the grain is an achene. Because of these differences and the high lysine content of

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buckwheat, the relation between amino acid composition and seed maturity in buckwheat was compared to that of maturing cereals.

MATERIALS AND METHODS

Each of the two tetraploid buckwheat cultivars, 'PA 66G99 W' (silverhull type) and 'Pennquad' (Japanese type) was grown in single adjacent plots near University Park, Pa., during the summers of 1971 and 1973. Each plot consisted of 12 rows 3.7 m long and 30.5 cm apart. The plots were irrigated twice to assure adequate moisture for vigorous growth. However, in 1973, very hot weather tended to cut off buckwheat development at a critical time. Since buckwheat has an indeterminate growth habit, seeds could be harvested at various stages of maturity on a single day. When there appeared to be adequate mature seed for laboratory analyses, the 10 center rows of each plot were cut, tied in bundles, placed in burlap bags, and dried at 78° C. After the plant material was dry, the seeds were removed by hand, and sorted into age groups with class centers of about 7, 14, 21, and 28 days. Estimates of ages were based on observations of seed development in unpublished field and greenhouse studies.

TABLE I
Kernel Weight[a] and Groat Percentage in Maturing PA 66G99 W and Pennquad Buckwheat

Cultivar and Maturing Stage (age in days)	Description	Kernel wt. mg		Groat % of Total	
		1971	1973	1971	1973
PA 66G99 W					
7	Shriveled	6.6	4.3	58.7	38.5
14	Partially filled	11.3	11.2	70.1	67.1
21	Filled, dark color, nonmottled	18.2	22.4	76.4	79.6
28	Filled, mottling complete, mature color characteristics	21.9	23.2	77.2	79.8
Pennquad					
7	Shriveled	11.5	6.4	46.0	24.0
14	Partially filled	17.7	17.2	59.4	59.0
21	Filled, dark color, nonmottled	28.9	30.2	69.5	71.1
28	Filled, mottling complete, mature color characteristics	34.3	35.7	74.9	76.8

[a]On "as-is" basis—dried to about 10% moisture.

The whole grains were separated into hulls and groats by hand; moisture and Kjeldahl-N were determined according to the Methods of Analysis of the American Society of Brewing Chemists (6). Amino acids were determined in acid hydrolysates with a Beckman 121 automatic amino acid analyzer by a described method (5, 7). Values are expressed in g of specific amino acid per 100 g total amino acid recovered. Average recoveries were 83.3% and 67.7% for groats and hulls, respectively. The low recoveries in the hulls were attributed to their high content of nonprotein nitrogenous compounds. All analyses were run at least in duplicate.

RESULTS AND DISCUSSION

During maturation, total kernel weight increased 3.0- to 5.6-fold (Table I) and was due mainly to an increase of the groat (from 1.7 mg to 18.5 mg in PA 66G99 W and from 1.5 mg to 27.4 mg in Pennquad). The increase in hull weight was small (from 2.7 mg to 4.7 mg and from 4.9 mg to 8.3 mg in PA 66G99 W and Pennquad, respectively). Groat weight increased up to eighteenfold and hull weight less than twofold. Mature Pennquad kernels weighed more than mature PA 66G99 W kernels, but the groat percentages did not differ markedly.

The large increase in groat weight was accompanied by a decrease in nitrogen content (Table II). The Kjeldahl-N content of hulls of mature buckwheat was only 1/4 to 2/3 that of immature hulls. Nitrogen content of groats from mature kernels was higher for Pennquad than for PA 66G99 W; nitrogen contents of hulls did not differ consistently between cultivars.

In both years, changes during maturation were similar in amino acid contents in hulls (Table III) and groats (Table IV) of both cultivars. To simplify presentation of data, the results from analyzing the 1971 crop grown under more normal conditions, only, are presented. During maturation, the main changes in amino acid content in the hulls were increases in histidine and glycine.

During maturation in the groat, there were large increases in arginine and

TABLE II
Kjeldahl-N Contents of Groat and Hull Fractions of Maturing PA 66G99 W and Pennquad Buckwheat

Cultivar and Maturity Stage (age in days)	Kjeldahl-N (%)[a] Hull 1971	Hull 1973	Groat 1971	Groat 1973
PA 66G99 W				
7	2.14	1.19	2.75	3.63
14	1.34	0.98	2.39	3.11
21	0.87	0.75	2.05	2.77
28	0.58	0.74	2.09	2.58
Pennquad				
7	1.27	1.12	3.50	3.97
14	0.99	0.88	3.40	3.53
21	1.02	0.75	2.70	2.98
28	0.65	0.70	2.69	2.89

[a]On "as-is" basis—dried to about 10% moisture.

TABLE III
Amino Acid Composition[a] of Acid Hydrolysates of Hulls from Maturing PA 66G99 W and Pennquad Buckwheat (1971)

Amino Acid	Maturity Stage (age in days)							
	PA 66G99 W				Pennquad			
	7	14	21	28	7	14	21	28
Lysine	6.5	7.0	7.1	7.0	7.3	7.2	7.3	7.1
Histidine	2.7	2.9	3.4	3.5	3.1	3.3	4.2	4.2
Ammonia	3.8	3.7	3.5	3.7	4.5	4.6	4.8	3.6
Arginine	5.2	4.9	4.7	4.3	4.9	5.0	4.3	5.7
Aspartic acid	11.2	11.2	10.9	10.8	10.9	10.7	10.3	10.3
Threonine	5.1	5.1	5.2	5.4	4.8	4.9	5.0	4.9
Serine	5.6	5.6	5.7	6.1	5.2	5.2	5.4	5.4
Glutamic acid	13.6	13.1	12.9	13.1	14.4	14.2	13.4	14.5
Proline	3.5	3.4	3.2	2.7	3.6	3.5	3.9	4.1
Cystine	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.3
Glycine	6.8	7.0	7.5	8.4	6.5	6.7	7.4	7.5
Alanine	6.4	6.5	6.5	7.1	6.3	6.4	6.4	6.0
Valine	6.6	6.7	6.8	6.6	6.5	6.4	6.6	6.3
Methionine	1.4	1.6	1.5	0.9	1.1	1.0	1.0	1.0
Isoleucine	5.0	5.1	5.1	4.8	5.0	4.9	4.9	4.6
Leucine	8.5	8.5	8.4	8.2	8.4	8.3	8.3	7.7
Tyrosine	2.9	2.6	2.7	2.4	2.7	2.7	2.1	2.5
Phenylalanine	5.0	5.0	5.1	5.0	4.8	4.9	4.7	4.6

[a]Grams per 100 g amino acids recovered.

TABLE IV
Amino Acid Composition[a] of Acid Hydrolysates of Groats from Maturing PA 66G99 W and Pennquad Buckwheat (1971)

Amino Acid	Maturity Stage (age in days)							
	PA 66G99 W				Pennquad			
	7	14	21	28	7	14	21	28
Lysine	6.9	6.7	6.4	5.9	7.2	6.8	6.4	6.1
Histidine	2.4	2.4	2.4	2.4	2.3	2.4	2.0	2.4
Ammonia	2.2	2.0	1.9	1.8	2.4	2.1	2.0	1.9
Arginine	7.6	8.7	9.2	9.5	7.4	8.1	9.3	10.1
Aspartic acid	11.3	11.4	11.4	11.4	11.1	11.3	11.1	11.2
Threonine	3.8	3.7	3.7	3.7	3.9	3.8	3.7	3.5
Serine	4.0	4.1	4.2	4.1	4.0	4.2	4.2	4.2
Glutamic acid	18.7	19.2	19.3	19.4	19.3	19.9	19.5	19.7
Proline	2.8	2.6	2.4	2.5	3.2	3.0	2.8	2.6
Cystine	1.3	1.5	1.4	1.5	1.1	1.2	1.5	1.6
Glycine	5.8	5.8	6.0	6.2	5.7	6.0	5.9	6.1
Alanine	5.5	5.0	4.8	4.8	5.9	5.2	4.8	4.6
Valine	5.7	5.6	5.4	5.4	5.7	5.6	5.5	5.3
Methionine	3.4	3.4	3.2	3.4	2.9	2.9	3.1	2.7
Isoleucine	4.3	4.1	4.1	4.0	4.3	4.2	4.1	3.9
Leucine	7.0	6.8	6.8	6.7	7.0	6.9	6.8	6.6
Tyrosine	2.8	2.6	2.6	2.6	2.2	2.0	2.5	2.5
Phenylalanine	4.5	4.6	4.7	4.8	4.4	4.6	4.8	4.8

[a]Grams per 100 g amino acids recovered.

large decreases in lysine, proline, alanine, and isoleucine (Table IV).

The contents of selected amino acids in the proteins of mature wheat (3), oat groats (4), pea ovules (8), and buckwheat groats are compared in Fig. 1; data were condensed and represent only samples harvested at the first developmental stage and at maturity.

The amino acid composition of cereals is markedly affected by the relatively high concentrations of storage proteins (indicated by high glutamic acid and proline values). Glutamic acid plus proline comprise up to 44% of the total amino acids in proteins of wheat, but only about half that amount in buckwheat and pea amino acids. Concentrations of glutamic acid plus proline increased during maturation of oats, and especially of wheat, but changed little in maturing buckwheat, and decreased in maturing peas. Changes in valine were small (except for wheat) and the sum of the two aromatic amino acids, tyrosine and phenylalanine, changed little in wheat and buckwheat but increased somewhat in oats and almost doubled in peas. Lysine decreased in wheat, oats, and buckwheat; in wheat, the decrease was from 3.8 to 2.6 g; in oats, from 7.6 to 4.2 g; and in buckwheat from 7.1 to 6.0 g. Consequently, mature oat and buckwheat groats retained high levels of lysine which is limiting in most cereals. Lysine

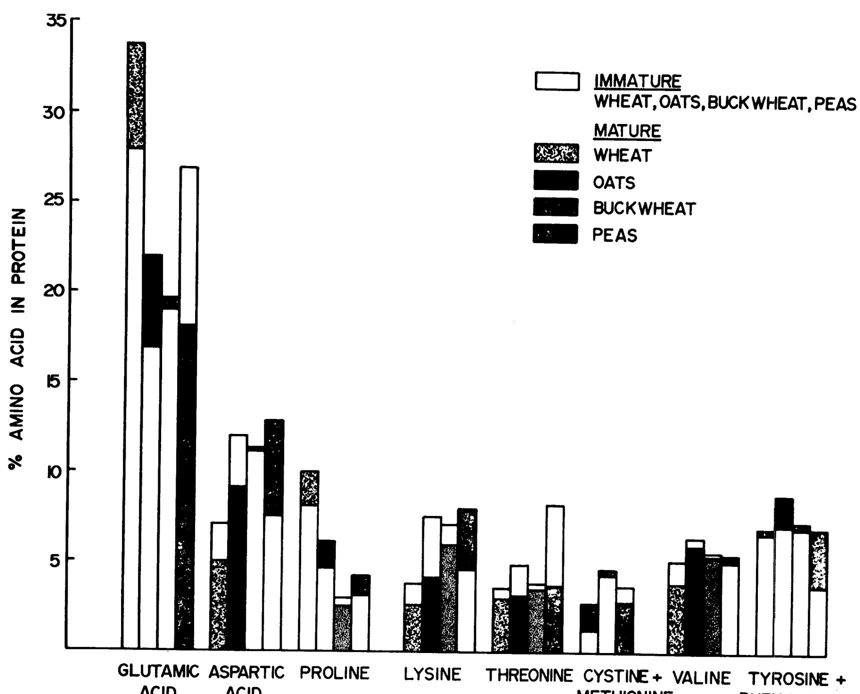

Fig. 1. Selected amino acids of immature and mature wheat, oats, buckwheat, and peas. The top line in each case represents the higher level of the two maturity stages. An empty upper part indicates the amino acid content of proteins in a specific sample was higher in the immature than in the mature sample. A shaded upper part indicates the amino acid content was higher in the mature than in the immature sample.

content of pea proteins increased from 4.7 to 8.0 g. Peas and buckwheat are, therefore, excellent sources of lysine in cereal-based diets. Threonine content differed only slightly among the mature cereals and was only slightly higher in buckwheat and peas than in cereals. Threonine, the second limiting amino acid in oats, has not thus far, been increased through breeding (7,9).

The S-containing amino acids are usually the first limiting amino acids in legume proteins (10). Cystine plus methionine contents of proteins in mature oat groats and peas were comparable (Fig. 1). (The missing bar for S-containing amino acids of wheat is due to lack of the relevant data in reference 3.) Good sources of S-containing amino acids are limited and their high contents in buckwheat would make it an excellent supplement.

Aspartic acid is a key intermediate in the biosynthesis of lysine in bacteria, algae, and higher plants (11). We recently have shown (12) that lysine content is highly correlated with aspartic acid content in barley and that high-protein high-lysine barley cultivars (Hiproly) are also rich in aspartic acid. Maturing buckwheat (unlike cereals) contains a high and stable level of aspartic acid. During maturation of peas, increases in aspartic acid paralleled increases in lysine (8). The aspartic:lysine ratio in maturing peas was fairly stable (1.6–1.7).

Finally, protein in buckwheat groats was remarkably stable in amino acid composition. This is not surprising as most proteins in mature buckwheat were shown (13) to be soluble (albumins and globulins). In wheat, protein solubility decreased rapidly during maturation (3). Amino acid composition differs markedly in soluble and storage proteins (insoluble in aqueous salt solutions). Apparently, therefore, the maturing buckwheat translocates and deposits into the groat, amino acids of fairly constant composition, but the maturing cereal grains synthesize, in advanced stages of maturity, mainly storage proteins which are rich in glutamic acid and proline and poor in lysine.

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