Plant Seeds as Protein Sources for Food or Feed. Evaluation Based on Amino Acid Composition of 379 Species

C. H. VanEtten,[1] W. F. Kwolek,[1] J. E. Peters,[1] and A. S. Barclay[2]

Amino acid analyses are reported for the first time on seeds from 165 plant species. For evaluation, the data were combined with results reported earlier on 214 other species. Based on the FAO provisional pattern for selected nutritionally essential amino acids, the seed proteins were generally adequate in leucine, phenylalanine, threonine, and valine. The mean methionine content for 35 species of Compositae, and the mean lysine content for 92 species of Cruciferae, and for 70 species of Leguminosae, were above the mean for all species. Percentages of methionine and isoleucine in seeds from most plant families were below FAO requirements. Seeds from Gramineae (including the common cereal grains) were low in lysine. Seed proteins from a number of species have a better pattern of essential amino acids than many crop seed sources. Many seed meals contained toxic or deleterious substances which must be inactivated or removed before the meals can be considered for food or feed.

The amino acid compositions of seed from 214 angiospermous species have been reported (Miller *et al.*, 1962a,b; VanEtten *et al.*, 1961b, 1963a). The data supplied basic information on the distribution of the nitrogenous constituents in a variety of plant seeds. This paper presents results on the amino acid composition of seeds from 165 additional species representing 136 genera and 47 plant families. The combined data from 379 species support generalizations made from the present authors' previous work.

In addition, plant seeds are evaluated as a source of food protein, based on their amino acid composition. Appraisals are made by comparison with the essential amino acid provisional patterns recommened by the Food and Agriculture Organization of the United Nations (FAO), (1957; WHO 1965). Such an evaluation is desirable as a part of the search for additional sources of food. Predictions of future food needs based on current rate of world population increase and food production emphasize the seriousness of this problem (Altschul, 1965; FAO, 1964; Hamilton, 1965).

From studies such as that of FAO (1964) it appears the most urgent need is to increase production of protein, especially of good nutritional quality. In the past the most practical source of food including protein has been cereals and other harvested seeds. Advantages are that food in seeds is in a concentrated, easily preserved form, and that seed crops can often be grown close to where they are needed. Such sources of food are being increased through development of superior varieties, better agronomic practices, and improved harvesting, storage, and processing methods.

Perhaps more food can be produced from lesser known domestic plants or by domestication of wild ones. New food crops may be developed that are adapted to areas now considered marginal for agriculture. Also, as the compositions of less familiar plants become known, we can be more confident of finding new sources of raw material for industry. Information presented here is germane to such attempts.

MATERIALS AND METHODS

Seed preparation, hydrolysis of seed proteins, and ion exchange chromatographic analyses of amino acids were carried out as described by VanEtten *et al.* (1961b). Selections of the species were made from an analytical compilation of more than 1650 samples studied for their content of crude protein, oil, and other components (Earle and Jones, 1962; Jones and Earle, 1966). Amino acid analyses were determined by the automated method of Spackman, Stein, and Moore (1958) with a model MS Beckman Spinco instrument. The 150-cm. column was operated at 30° and 50° C. in order to separate hydroxyproline from aspartic acid.

Amino acid compositions cover species from plant families as follows: Leguminosae, 24; Cruciferae, 19; Compositae, 18; Labiatae, 10; Boraginaceae and Euphorbiaceae, five each; Rutaceae, four; Amaryllidaceae, Apocynaceae, Polemoniaceae, and Umbelliferae, three each; and the remaining 68 species from 53 different plant families. Of the angiosperms, seven are monocots and 154 dicots. For the first time, four species of the gymnosperms are reported.

AMINO ACID COMPOSITION AND VARIABILITY

Mean Composition and Variation from the Mean. Crude protein and oil content of the seed, seed plus pericarp, or seed minus seed coat for the 379 species calculated on the dry basis were: crude protein (nitrogen × 6.25), mean 27.9%, extremes 5.6 to 71.0%, standard deviation 10.2; oil, mean 26.9%, extremes 0.8 to 66.0%, standard deviation 15.2.

The means for each amino acid (Table I) for the 379 species are similar to those already reported for 200 species by VanEtten *et al.* (1963a). The greatest changes in variation, as measured by relative standard deviations, are in arginine, lysine, phenylalanine, and tyrosine (see last column of Table I). For all 379 species, lysine, methionine, arginine, glycine, phenylalanine, tyrosine, glutamic

[1] Northern Regional Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Ill.

[2] Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

Table I. Summary of Amino Acid Compositions of Seed from 379 Species[a]

Amino Acid	Grams per 16 Grams Nitrogen: Mean	Extremes	Std. Dev.	Relative Standard Deviation: 379 species	200[b] species	Change
Lysine	4.39	7.5–1.3	1.19	27.1	24.2	2.9
Methionine	1.56	3.5–0.5	0.469	30.1	29.8	0.3
Arginine	8.58	20.1–3.1	2.57	29.9	26.8	3.1
Glycine	4.85	12.6–2.6	1.00	20.6	19.4	1.2
Histidine	2.27	4.3–1.2	0.396	17.4	15.0	2.4
Isoleucine	3.60	5.8–1.9	0.543	15.1	15.3	0.2
Leucine	6.05	13.7–3.2	0.947	15.7	16.7	1.0
Phenylalanine	3.87	10.1–2.0	0.792	20.5	16.3	4.2
Tyrosine	2.88	5.3–1.6	0.601	20.9	16.8	4.1
Threonine	3.31	5.0–1.6	0.562	17.0	15.9	1.1
Valine	4.52	6.7–2.3	0.698	15.4	15.6	0.2
Alanine	3.96	8.8–1.5	0.709	17.9	18.7	0.8
Aspartic acid	8.41	14.5–4.2	1.51	17.9	17.6	0.3
Glutamic acid	16.76	33.1–8.6	3.36	20.0	20.8	0.8
Proline	4.33	11.3–1.1	1.27	29.3	27.5	1.8
Serine	4.12	6.7–2.3	0.645	15.7	16.5	0.8

[a] Statistical terminology recommended by *Anal. Chem.* (1961).
[b] From amino acid composition of seed meals from 200 plant species (VanEtten *et al.*, 1963a).

acid, and proline varied the most (relative standard deviation range of 20.0 to 30.1). The remaining amino acids have a relative standard deviation range of 15.1 to 17.9. In this summation, hydroxyproline was not included, as it has been found only in such tissues as seed coat and pericarp (VanEtten *et al.*, 1961a). Of the 165 species reported in Table II, the 10 species analyzed as seed kernels without seed coat or pericarp contained no hydroxyproline. This analysis is additional evidence that storage and embryo protein do not contain hydroxyproline.

The frequency distributions for lysine, isoleucine, and valine (Figure 1) appear symmetrical about the mean. When scattered outliers of the extreme greater than the mean are not considered, the distribution also appears symmetrical for methionine, leucine, and phenylalanine. A frequency distribution for the remaining amino acids often showed a wide scatter of outliers at the extreme greater than the mean. A possible explanation is that seed from an occasional species contains a less familiar or unidentified amino acid or nitrogenous base which elutes with the known amino acid. However, the two high leucine values are from the few species of Gramineae reported in this study. By microbiological assay Taira (1962a,b; 1963) reports leucine content in this range for members of the Gramineae, subfamily Panicoideae. Deyoe and Shellenberger (1965) give high leucine values for grain sorghums.

Amino Acid Composition in Relation to Plant Groups. The mean analytical results shown in Table III were calculated from data on 379 species. The arithmetic mean and the number of samples involved are given for all families sampled five or more times. At the bottom of the table is listed the standard deviation per observation calculated from variability between samples from the same family. Sources of variation involved in the standard deviation include variation among genera, species, and determinations, as well as environmental effects. Comparing means for different families is complicated by unequal numbers of samples and unequal numbers of genera and species in families. Even more important, the number of

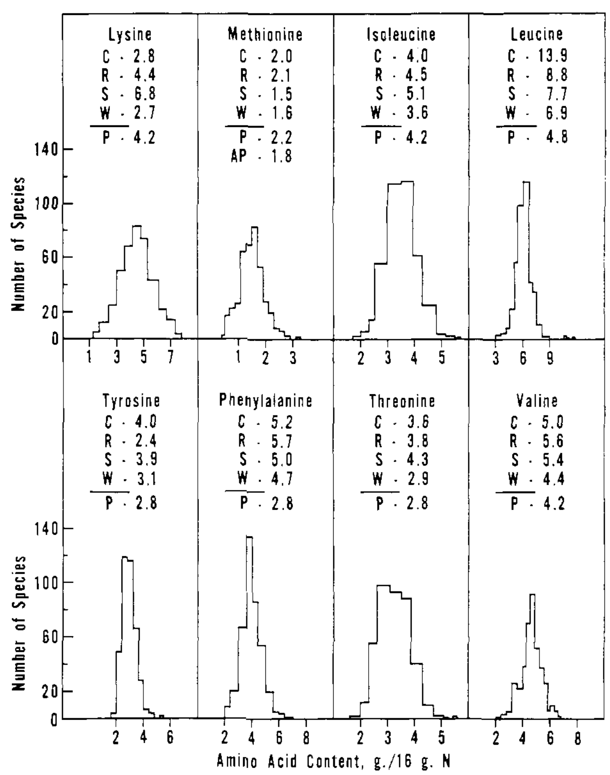

Figure 1. Frequency distribution of nutritionally essential amino acids in plant seeds from 379 species compared with the estimated requirement for man (FAO, 1957) and with the amino acid content of corn (Mertz *et al.*, 1965), rice (Cagampang *et al.*, 1966) soybeans (Rackis *et al.*, 1961), and wheat (Waggle *et al.*, 1967)

Requirements for methionine and for phenylalanine are based on protein containing 2% or more cystine and 2.8% or more tyrosine, respectively; with less cystine and tyrosine, more methionine and phenylalanine would be required: C = corn; R = rice; S = soybeans; W = wheat; P = FAO (1957) provisional pattern; AP = WHO (1965) adjusted provisional pattern

Table II. Amino Acid Composition from Analysis of Seeds from 165 Species[a]

Grams amino acid per 16 grams of nitrogen

Seed Source	Protein, %	Oil, %	Lysine	Methionine	Arginine	Glycine	Histidine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Alanine	Aspartic Acid	Glutamic Acid	Hydroxyproline	Proline	Serine	% Nitrogen as Ammonia	% Nitrogen as Amino Acids
GYMNOSPERMAE																					
Ginkgoales																					
Ginkgoaceae																					
Ginkgo biloba	10.0	3.1	3.7	1.7	10.8	4.1	1.8	3.4	6.0	3.3	2.8	5.0	5.3	4.5	10.3	13.2	0.2	9.3	4.8	8.4	79.6
Coniferales																					
Cephalotaxaceae																					
Cephalotaxus harringtonia var. *drupacea*	12.5	65.2	6.6	2.3	10.2	4.9	2.6	4.8	6.8	5.3	3.7	3.0	5.6	4.6	8.9	19.1	0.9	5.6	5.3	8.4	79.7
Pinaceae																					
Pinus pinea	35.6	51.7	2.6	1.7	20.1	4.2	2.1	3.0	5.8	3.6	3.2	2.3	4.3	4.2	7.3	16.8	0.0	3.9	4.3	7.2	96.6
Cupressaceae																					
Chamaecyparis lawsoniana	11.9	24.7	2.8	2.0	12.6	5.5	1.8	3.3	5.4	4.4	2.0	2.9	4.6	4.0	8.1	17.4	0.8	4.1	3.6	10.7	80.3
ANGIOSPERMAE																					
Monocotyledoneae																					
Helobiae																					
Alismataceae																					
Sagittaria papillosa	19.4	23.0	2.9	1.1	4.2	6.0	1.4	2.5	4.6	2.8	3.0	3.2	3.7	3.3	6.4	11.7	2.8	3.7	4.1	12.2	57.0
Glumiflorae																					
Gramineae																					
Aegilops crassa var. *macrothera*[b]	18.4	3.1	2.8	1.7	5.1	4.6	2.4	3.5	6.8	5.4	2.7	3.1	4.4	4.5	5.5	29.5	0.0	8.8	4.6	16.9	77.4
Briza spicata	15.6	21.0	4.2	1.5	7.4	5.4	2.2	3.7	6.4	5.3	3.8	3.4	4.7	4.8	8.5	16.2	0.0	4.5	4.2	10.7	73.8
Principes																					
Palmae																					
Butia capitata	15.6	56.5	4.5	2.0	13.8	4.1	2.0	3.1	5.7	4.2	2.4	3.1	4.5	4.3	7.7	17.9	0.2	3.5	3.6	10.5	77.7
Liliiflorae																					
Liliaceae																					
Asphodelus microcarpus	38.1	13.6	3.7	1.2	12.8	6.5	2.2	3.0	4.9	3.1	2.8	2.7	4.3	3.4	8.0	17.5	0.3	3.0	3.9	11.8	80.0
Amaryllidaceae																					
Agave schottii	29.4	21.4	4.5	1.7	12.4	3.6	2.4	3.0	5.1	3.3	3.5	2.5	3.9	3.2	6.6	15.4	2.0	3.7	3.9	9.7	75.2
Pancratium maritimum	21.9	37.2	5.5	2.1	9.8	4.9	2.0	4.4	6.4	4.8	3.1	3.4	6.1	5.0	9.1	16.6	0.0	3.5	4.9	8.4	80.5
Dicotyledoneae																					
Verticillatae																					
Casuarinaceae																					
Casuarina torulosa	48.8	41.9	2.5	1.4	14.3	4.8	2.5	3.4	7.1	4.7	2.8	2.6	4.3	3.6	9.1	15.7	0.0	3.9	3.9	9.0	85.8
Urticales																					
Urticaceae																					
Boehmeria cylindrica[b]	20.6	25.9	3.2	2.2	9.2	4.9	1.9	3.3	6.4	4.2	2.8	3.6	5.1	4.1	9.1	15.6	0.5	4.5	4.2	9.5	75.5
Proteaceae																					
Protea barbigera[c]	68.8	31.4	1.3	0.8	19.1	3.3	2.3	2.6	4.8	3.0	3.3	1.6	2.9	2.8	8.5	18.8	0.0	3.0	2.6	8.8	83.2
Aristolochiales																					
Aristolochiaceae																					
Aristolochia maurorum	21.3	23.4	4.3	1.6	8.5	3.9	1.8	3.0	5.4	2.8	3.3	2.9	4.6	7.2	10.1	15.1	1.0	4.3	4.2	11.8	71.0

Table II. Continued

Seed Source	Protein, %	Oil, %	Lysine	Methionine	Arginine	Glycine	Histidine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Alanine	Aspartic acid	Glutamic Acid	Hydroxyproline	Proline	Serine	% Nitrogen as Ammonia	% Nitrogen as Amino Acids
Polygonales																					
Polygonaceae																					
Eriogonum alatum[b]	63.8	8.6	4.1	1.9	10.1	5.8	2.2	3.0	5.1	3.4	2.5	2.8	4.1	4.3	7.5	15.9	0.0	3.2	4.0	11.8	71.4
Centrospermae																					
Chenopodiaceae																					
Spinacia oleracea[b]	24.4	7.0	4.0	1.8	13.8	7.1	3.4	4.3	6.2	4.3	3.6	3.4	4.8	3.6	9.2	21.2	0.3	4.2	4.5	13.7	90.1
Aizoaceae																					
Mesembryanthemum crystallinum	31.3	7.8	2.9	1.4	5.3	12.6	3.2	2.8	4.2	3.6	4.7	2.9	3.0	2.7	8.1	15.5	0.0	3.3	4.1	9.5	69.1
Ranales																					
Lardizabalaceae																					
Akebia trifoliata	15.6	38.9	5.9	1.4	7.4	4.0	2.2	4.3	7.1	4.4	3.8	3.0	5.4	3.8	10.2	16.2	1.4	4.8	5.2	10.5	77.9
Lauraceae																					
Litsea glaucescens	15.0	10.9	4.2	1.3	8.4	4.6	1.6	4.1	7.4	5.1	4.4	3.7	5.4	4.6	10.1	14.5	0.8	4.1	5.2	9.8	77.8
Rhoeadales																					
Capparaceae																					
Polanisia viscosa	16.3	26.2	2.3	1.7	9.8	4.7	2.3	3.4	5.4	4.1	2.1	2.8	4.5	3.7	7.3	15.7	0.0	4.1	2.3	16.0	68.1
Papaveraceae																					
Glaucium arabicum	23.8	34.7	4.3	2.0	9.9	6.3	2.2	3.6	5.8	3.6	5.6	3.4	5.3	3.6	11.9	16.8	0.4	4.1	3.7	10.8	77.9
Fumariaceae																					
Adlumia fungosa	14.4	31.0	2.6	2.0	5.3	3.3	1.6	2.4	4.2	2.4	2.0	2.6	3.6	2.9	5.7	11.8	1.5	3.2	3.6	17.4	52.6
Cruciferae																					
Alyssum dasycarpum	28.8	34.3	4.8	1.9	8.3	7.5	2.3	4.1	6.4	4.1	3.2	4.2	5.6	4.5	9.1	15.8	1.5	4.9	4.9	11.9	82.1
Arabidopsis thaliana	18.5	42.9	5.2	1.8	5.5	6.2	2.0	4.2	6.8	4.9	3.1	4.4	5.1	5.1	8.0	15.5	1.0	5.0	4.4	11.7	74.8
Carrichtera annua	31.3	18.6	3.9	1.4	7.1	5.2	2.2	2.7	4.8	3.5	2.4	3.8	3.7	4.7	6.9	16.1	1.4	6.5	4.0	12.6	66.7
Caulanthus inflatus	28.8	30.5	4.7	1.5	6.8	6.2	2.1	3.7	6.4	3.5	2.8	4.0	5.2	2.1	8.6	15.5	1.4	5.0	4.5	11.7	71.3
Crambe orientalis	31.3	43.1	5.7	1.8	5.8	4.2	2.7	3.6	6.0	3.5	2.7	3.9	4.7	4.6	5.3	16.1	0.8	6.7	3.7	14.5	71.0
Erucaria hispanica	35.0	31.9	3.3	1.7	8.7	5.7	2.4	3.2	5.7	4.5	3.2	3.4	4.7	4.0	7.2	20.0	1.0	5.3	3.5	16.7	73.1
Erysimum cuspidatum	35.6	32.8	4.8	1.7	6.8	5.8	2.6	3.9	7.2	4.1	3.0	3.9	4.8	4.6	7.3	15.9	0.8	6.0	3.7	14.1	73.9
Hirschfeldia incana	28.8	30.6	5.0	1.6	9.4	4.8	2.8	3.8	6.3	4.1	2.8	3.6	4.8	3.8	6.0	16.6	1.4	6.4	3.6	15.8	77.6
Malcolmia africana	32.5	30.6	3.6	1.6	6.8	8.0	2.4	3.8	6.1	4.5	2.9	3.4	5.0	3.7	7.8	18.0	0.7	6.2	3.7	13.2	74.6
Nasturtiopsis arabica	30.6	33.4	3.7	1.6	6.5	6.0	2.0	3.6	5.7	3.7	2.8	3.7	4.6	4.3	7.1	15.8	0.7	4.9	3.9	15.4	67.7
Peltaria angustifolia	24.4	32.4	5.7	1.4	7.8	6.2	2.6	3.8	6.6	4.1	3.5	4.5	5.4	4.7	8.7	16.0	1.1	6.0	4.0	13.3	83.1
Rapistrum rugosum	32.5	35.8	4.6	1.7	7.6	4.8	2.7	3.7	6.5	4.1	2.9	3.4	5.1	4.1	6.7	15.9	0.7	6.3	3.1	13.5	76.8
Rapistrum rugosum subsp. *orientale*	33.1	36.2	4.8	1.7	9.1	5.3	2.8	4.0	6.9	4.5	2.8	3.5	5.4	4.2	6.4	17.3	0.8	6.8	3.2	12.6	80.3
Reboudia pinnata	35.0	30.6	2.9	1.7	8.6	5.4	2.2	3.4	6.0	3.6	2.8	3.5	4.4	3.8	6.9	18.1	0.8	8.2	3.5	12.9	74.3
Savignya parviflora	25.0	19.0	4.5	1.6	5.9	7.3	2.1	3.5	5.2	3.8	2.6	4.2	5.4	4.8	7.6	19.6	1.5	4.8	4.8	16.7	77.3
Schimpera arabica	36.9	38.6	3.6	1.6	8.0	5.7	2.4	3.5	6.6	...	...	3.4	4.8	4.0	7.3	18.1	0.8	5.5	3.3	14.6	71.4
Sinapis alba	31.9	28.0	5.9	1.7	6.1	6.1	2.9	4.1	7.3	4.1	3.3	4.6	5.6	4.5	7.9	18.0	1.1	6.4	4.3	15.0	78.7
Sisymbrium irio	36.3	30.2	4.5	1.7	7.2	5.8	2.4	3.4	6.1	3.7	3.2	4.2	5.3	5.2	8.3	16.1	1.3	6.5	4.5	12.8	80.7
Thysanocarpus radians[b]	18.1	10.3	5.1	2.0	6.7	5.6	2.3	4.0	7.3	4.2	2.4	3.9	5.6	4.9	9.0	17.1	0.4	5.6	3.7	15.0	78.3
Moringaceae																					
Moringa pterygosperma[c]	41.9	33.5	1.7	1.6	12.8	4.5	2.2	2.9	5.1	4.1	2.0	2.3	3.6	3.7	4.2	17.6	0.0	5.0	2.6	14.4	74.6

Rosales																					
Saxifragaceae																					
Deutzia scabra	26.3	33.8	4.4	1.7	11.4	6.0	2.1	3.2	6.0	3.6	2.8	3.1	4.2	3.7	8.3	19.0	0.0	3.8	4.0	9.1	80.9
Hydrangea petiolaris	29.4	38.0	5.1	2.3	13.6	5.8	2.6	4.1	7.6	4.9	3.3	3.5	5.1	4.3	9.3	21.3	0.3	4.5	4.3	11.0	...
Rosaceae																					
Kerria japonica	45.0	45.3	2.1	0.7	10.7	4.2	1.9	2.6	6.3	2.6	3.0	2.2	3.8	3.4	9.3	19.8	0.0	2.9	3.2	12.4	67.2
Prunus webbii	24.4	52.2	2.6	0.7	9.2	5.8	2.0	3.4	6.3	2.9	2.6	2.7	4.3	4.1	10.6	22.0	0.0	5.3	3.6	14.7	79.0
Leguminosae																					
Abrus precatorius	19.4	2.8	5.4	1.2	4.8	3.9	3.2	3.4	5.9	3.6	3.0	3.5	3.9	3.5	8.2	13.7	0.4	8.6	4.4	9.2	69.8
Astragalus panduratus	52.5	8.5	2.8	0.6	8.1	4.0	1.9	2.3	3.9	2.3	2.2	2.2	2.6	2.7	6.2	12.8	0.0	2.9	3.2	7.6	78.2
Baptisia leucantha	37.5	10.2	4.7	0.8	10.9	4.7	2.0	3.3	5.7	3.3	3.2	2.6	3.4	2.8	8.4	20.0	0.7	3.6	4.0	9.5	77.4
Cajanus cajan	21.9	1.5	6.8	1.2	5.9	3.7	3.4	3.8	7.2	10.0	3.1	3.6	4.5	4.3	9.8	20.1	0.0	4.4	4.7	7.7	80.7
Calycotome villosa	31.3	3.0	5.9	0.9	8.2	5.2	2.3	4.1	7.3	4.1	3.5	3.5	4.6	3.6	9.5	19.2	0.3	3.8	4.5	8.9	76.8
Cassia occidentalis	20.6	2.7	6.2	1.9	7.8	4.2	2.3	3.9	6.9	5.1	3.1	3.9	5.1	4.6	10.1	18.0	0.0	3.7	5.3	10.4	76.8
Cicer arietinum	19.4	5.5	7.2	1.4	8.8	4.0	2.3	4.4	7.6	6.6	3.3	3.5	4.6	4.1	11.7	16.0	0.0	4.3	5.2	8.6	82.2
Dalea nutans	26.9	10.9	4.9	0.8	10.6	4.4	2.1	3.1	5.3	3.3	3.0	2.7	3.7	3.3	10.5	15.3	0.0	3.6	3.9	10.1	73.0
Dolichos lablab	23.4	1.1	6.8	0.9	6.6	4.6	3.2	4.4	8.5	4.9	3.6	4.2	5.2	4.5	12.0	15.7	0.6	4.3	5.4	9.4	80.8
Ebenus laguroides	51.3	12.7	5.2	1.5	13.0	4.1	...	3.7	6.1	4.2	2.5	3.4	4.0	4.2	9.6	18.3	0.0	4.5	4.6	10.8	88.0
Hedysarum fontanesii	55.6	10.0	3.9	1.0	10.3	3.6	2.5	3.2	5.0	3.3	2.5	2.8	3.4	3.1	8.1	14.3	0.0	3.2	3.7	8.0	86.0
Lathyrus sylvestris	33.4	0.8	5.8	0.7	7.5	3.7	2.6	3.7	6.4	3.8	2.6	3.4	4.4	3.9	10.2	14.8	0.0	3.6	4.3	9.8	82.6
Lens culinaris	26.9	0.8	6.7	0.6	7.8	3.7	2.1	3.8	6.6	4.2	2.9	3.3	4.2	3.5	10.9	14.5	0.0	3.5	4.4	8.4	73.7
Melilotus alba	39.4	5.9	5.7	1.3	9.3	4.4	2.7	3.9	6.9	4.8	3.2	3.1	4.4	3.6	9.9	15.5	0.0	4.2	4.4	8.4	75.9
Onobrychis aurantiaca	57.5	13.4	4.9	1.7	10.6	5.0	4.3	3.3	5.4	3.0	2.8	3.0	3.7	3.3	10.7	14.2	0.0	3.1	4.0	8.4	79.2
Ormosia jamaicensis	12.5	9.3	4.1	0.5	4.0	2.6	1.4	2.3	4.7	2.5	2.6	2.3	2.6	2.4	5.6	10.7	0.4	2.7	2.5	7.4	46.6
Pisum sativum var. *arvense*	25.6	0.9	7.0	0.8	8.8	4.2	2.2	3.9	6.8	4.3	3.3	3.5	4.3	3.8	11.2	15.7	0.0	4.2	4.5	7.9	79.3
Retama raetam	25.6	2.8	4.9	0.8	8.0	4.0	2.3	3.5	6.4	3.6	3.2	2.8	3.7	3.1	8.2	19.8	0.6	4.2	3.5	7.7	79.7
Scorpiurus subvillosa	35.0	2.0	4.5	1.3	10.9	4.5	2.2	3.2	5.0	4.9	3.3	3.0	3.4	3.5	9.2	14.2	0.0	3.0	4.1	8.5	86.6
Spartium junceum	34.4	12.4	5.3	1.0	8.8	4.6	2.3	4.0	7.2	4.1	3.8	3.3	4.3	3.6	9.6	18.9	0.4	4.2	4.1	9.7	75.7
Stizolobium deeringianum	29.4	5.6	6.3	1.1	6.6	4.2	2.3	4.7	7.0	4.4	4.8	4.0	4.9	3.4	11.6	11.8	0.0	5.5	4.1	8.5	75.0
Trigonella arabica	28.1	3.3	5.4	1.4	11.4	5.6	2.6	3.9	6.3	4.2	2.9	3.4	4.6	3.8	10.4	16.3	0.0	4.4	4.5	9.1	84.2
Vicia angustifolia	47.5	6.2	3.4	0.9	10.4	4.6	1.8	2.9	5.0	3.6	2.4	2.6	3.4	3.0	8.4	14.4	0.0	3.5	4.0	7.3	77.6
Vicia gigantea	38.1	1.2	4.1	0.6	5.4	2.7	1.7	2.9	4.9	...	...	2.6	3.3	2.9	7.3	11.1	0.2	2.7	3.1	8.5	75.9
Geraniales																					
Geraniaceae																					
Erodium gruinum[b]	20.6	10.7	5.0	1.9	8.9	5.0	2.1	3.5	6.1	4.4	2.5	4.0	5.2	4.6	9.3	17.0	0.0	4.1	4.3	10.1	78.5
Linaceae																					
Linum usitatissimum	25.6	40.4	3.6	1.7	9.0	5.8	1.9	4.0	5.6	4.3	2.4	3.5	4.3	4.1	9.2	18.5	0.0	3.7	4.8	11.4	71.1
Zygophyllaceae																					
Peganum harmala	29.4	15.4	2.8	0.8	6.0	4.1	1.2	2.0	3.2	2.0	2.2	2.0	2.8	2.2	6.0	9.6	1.4	2.4	2.7	6.3	41.6
Tribulus terrestris	38.8	37.8	3.3	2.0	12.6	5.4	2.4	3.4	5.6	4.2	3.1	2.6	4.9	3.4	9.3	20.2	0.0	4.2	3.3	11.7	82.8
Rutaceae																					
Boronia megastigma	20.0	32.3	3.8	1.2	10.7	5.9	2.1	3.6	6.6	3.2	3.5	2.6	5.2	3.5	10.0	18.9	0.0	3.7	3.9	15.0	80.3
Dictamnus albus	24.4	36.2	3.7	1.5	9.1	4.6	1.9	3.2	5.6	3.1	2.9	2.7	4.4	3.1	9.1	19.0	0.0	3.3	3.8	15.4	71.9
Phellodendron amurense	35.8	51.7	2.8	1.8	10.8	5.7	2.1	3.9	6.7	3.7	4.1	2.7	5.1	3.2	8.8	23.4	0.0	3.4	4.2	13.3	81.1
Zanthoxylum schinifolium	36.3	54.4	3.1	1.5	10.7	4.7	1.7	3.5	7.0	3.6	4.5	3.0	5.0	3.6	9.5	22.6	0.0	3.6	4.5	13.1	82.3
Simaroubaceae																					
Alvaradoa amorphoides	25.0	58.8	4.1	2.0	10.4	4.3	2.1	3.3	6.7	3.8	3.1	3.5	5.3	4.0	7.9	17.1	0.7	4.3	4.8	7.4	79.3
Malpighiaceae																					
Malpighia umbellata[c]	41.9	45.8	2.3	1.4	12.2	4.8	1.6	3.7	6.9	4.9	2.7	2.6	4.6	4.6	9.9	19.2	0.0	4.1	4.3	11.6	84.2
Euphorbiaceae																					
Chrozophora tinctoria[c]	38.1	54.3	2.5	2.1	13.8	4.4	2.3	4.4	6.2	4.4	2.9	3.7	6.0	5.3	10.4	17.8	0.0	4.0	4.4	10.9	90.8
Euphorbia cybirensis	24.4	42.0	2.6	2.8	13.6	5.2	2.6	4.3	6.3	5.0	2.7	3.3	6.3	4.3	11.4	18.1	0.5	4.4	4.8	10.2	93.4
Euphorbia lagascae	25.6	42.2	4.0	2.6	12.5	4.3	2.4	4.4	6.4	5.3	2.6	3.6	5.6	4.6	11.6	16.2	0.1	4.0	4.5	11.4	91.1

Table II. Continued

Seed Source	Protein, %	Oil, %	Lysine	Methionine	Arginine	Glycine	Histidine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Alanine	Aspartic Acid	Glutamic Acid	Hydroxyproline	Proline	Serine	% Nitrogen as Ammonia	% Nitrogen as Amino Acids
Euphorbia paralias	21.9	41.0	3.8	2.1	11.6	5.2	2.4	4.7	6.4	4.8	2.4	3.3	6.0	4.7	11.6	17.1	0.4	4.9	5.0	9.6	85.0
Euphorbia segetalis	22.5	39.8	3.7	2.0	9.7	4.5	2.2	3.9	5.8	4.6	2.0	3.0	4.9	4.1	10.5	14.9	0.3	4.6	4.3	9.2	76.8
Sapindales																					
Anacardiaceae																					
Rhus canadensis	16.3	13.4	4.3	1.4	8.0	3.8	2.0	3.5	6.2	2.8	1.6	2.6	4.3	3.4	7.5	18.6	0.7	3.3	4.8	11.9	68.1
Aquifoliaceae																					
Ilex crenata	24.4	48.0	3.9	1.4	11.1	4.7	1.9	3.8	7.2	3.6	2.7	3.0	4.8	4.5	8.5	20.5	0.0	3.5	6.4	15.5	85.0
Salvadoraceae																					
Salvadora oleoides	18.1	40.9	4.6	1.6	8.6	4.2	2.4	3.0	5.5	4.8	2.6	3.1	4.4	4.5	6.9	12.7	1.2	4.0	3.8	13.1	73.7
Rhamnales																					
Rhamnaceae																					
Rhamnus purshiana[c]	25.6	56.9	3.5	1.0	8.0	4.3	2.0	3.6	7.8	3.8	3.3	2.6	4.5	3.8	10.7	22.4	0.0	3.5	4.8	12.9	76.9
Vitaceae																					
Parthenocissus quinquefolia	15.6	25.8	3.6	1.3	6.3	7.2	1.8	3.3	5.9	3.5	2.8	3.0	4.7	3.9	7.0	20.3	0.4	3.5	4.1	14.5	71.0
Malvales																					
Tiliaceae																					
Corchorus olitorius	21.3	14.1	7.2	1.5	4.8	4.3	1.7	3.1	5.6	4.4	2.7	3.3	4.0	3.9	10.1	16.0	0.0	3.8	3.9	10.5	63.6
Malvaceae																					
Gossypium herbaceum[c]	36.9	38.4	4.6	1.6	12.4	4.4	2.9	3.4	6.1	5.5	3.2	3.4	4.9	4.1	9.8	21.1	0.0	3.8	4.4	10.4	88.0
Lavatera trimestris	26.3	16.9	5.9	1.9	7.8	6.3	3.2	3.4	5.9	4.1	3.5	3.4	4.8	4.3	11.3	15.6	0.3	3.4	5.1	10.1	80.9
Parietales																					
Cochlospermaceae																					
Amoreuxia palmatifida	11.9	14.0	4.4	1.4	6.9	3.9	1.7	3.4	5.8	3.8	2.2	3.0	4.4	4.4	7.7	16.3	0.4	3.9	3.7	9.3	67.6
Loasaceae																					
Mentzelia decapetala	21.3	42.4	3.1	1.5	9.1	4.4	2.0	3.1	5.5	3.0	2.5	3.1	4.0	3.4	6.5	17.8	3.6	3.2	4.3	11.4	71.6
Opuntiales																					
Cactaceae																					
Ferocactus alamosanus var. *platygonus*	18.8	17.2	1.9	3.5	16.0	6.5	2.5	2.8	5.4	4.0	3.8	2.6	3.4	2.9	6.3	19.6	0.6	4.2	3.4	8.6	89.7
Pachycereus pecten-aboriginum	29.4	32.0	2.8	1.9	13.9	5.6	3.5	3.5	6.3	4.8	3.9	3.1	4.8	3.6	7.1	17.1	5.4	5.4	4.0	8.8	87.6
Myrtiflorae																					
Thymelaeaceae																					
Daphne gnidioides	30.6	58.1	2.6	1.9	13.9	5.0	2.2	3.8	6.9	4.8	2.8	3.2	5.1	4.5	10.1	16.4	0.0	4.0	4.4	9.4	87.4
Daphne mezereum[c]	24.4	65.4	3.4	2.5	14.1	5.1	2.4	3.8	7.1	4.8	2.2	3.1	5.2	4.9	10.5	18.4	0.0	4.4	4.4	10.0	93.9
Elaeagnaceae																					
Elaeagnus pungens[c]	42.5	23.1	3.9	1.1	11.2	4.9	1.7	2.8	5.9	3.1	2.8	2.7	3.6	3.3	9.2	25.2	0.0	3.5	4.6	9.0	80.9
Onagraceae																					
Clarkia amoena	31.3	34.6	3.2	2.2	11.8	6.6	2.3	3.6	6.5	4.6	3.1	2.8	4.7	4.1	9.1	17.9	0.4	3.6	4.4	10.4	85.3
Gaura villosa	37.5	43.9	2.0	1.8	12.3	6.6	2.2	3.5	6.5	4.8	3.3	2.5	4.7	3.8	7.8	20.5	0.2	3.0	4.9	10.9	84.0
Umbelliflorae																					
Umbelliferae																					
Bifora americana	9.4	17.9	4.1	1.9	4.1	6.5	2.3	3.0	3.2	3.4	2.3	2.5	4.3	3.6	10.2	31.0	0.0	3.4	3.6	18.8	72.6
Ferula communis[b]	28.1	9.2	4.3	1.1	6.9	5.2	2.0	3.1	4.3	3.6	2.1	2.5	3.5	3.4	9.6	14.3	1.8	3.8	3.6	10.1	62.5
Prangos pabularia	33.1	24.0	4.3	1.9	5.9	6.6	1.9	3.7	5.4	4.2	2.2	2.8	4.6	5.1	10.4	21.2	1.2	4.4	3.9	15.0	75.4

Ericales																					
Ericaceae																					
Arbutus unedo	33.1	36.8	2.1	1.6	13.0	5.6	1.7	2.8	6.4	3.5	3.0	2.5	4.5	4.6	9.1	22.6	0.0	4.4	3.5	15.7	82.5
Primulales																					
Theophrastaceae																					
Jacquinia pungens	10.6	11.1	3.5	1.1	11.6	4.1	1.6	2.9	6.2	2.7	1.9	3.1	4.3	4.2	7.7	16.3	0.4	4.4	3.3	8.1	75.3
Myrsinaceae																					
Rapanea laetevirens[b]	5.6	20.2	4.1	1.4	5.6	4.3	1.8	3.4	5.8	3.4	2.2	3.2	4.0	4.1	7.4	11.3	0.6	3.4	3.4	7.6	45.8
Ebenales																					
Symplocaceae																					
Symplocos paniculata	21.3	51.7	3.1	2.0	17.7	3.5	1.9	3.3	5.9	3.3	2.0	2.6	4.0	3.8	7.1	14.7	0.2	3.3	3.3	9.0	83.5
Styracaceae																					
Styrax obassia[c]	17.5	46.6	4.7	2.2	10.1	5.7	2.1	5.0	7.4	4.4	3.2	3.8	5.5	5.7	10.8	16.9	0.0	4.9	4.1	9.0	86.2
Contortae																					
Oleaceae																					
Fraxinus americana	25.0	33.4	4.9	2.1	8.0	5.3	2.2	4.3	7.3	5.7	3.8	4.1	5.5	4.9	10.2	18.2	0.0	3.7	5.1	13.0	84.9
Gentianaceae																					
Frasera parryi	15.6	27.0	5.5	1.8	6.8	6.0	2.4	4.4	7.9	4.1	3.1	4.3	5.8	5.2	10.7	16.1	0.0	4.2	4.6	10.3	80.6
Apocynaceae																					
Nerium oleander	30.0	29.4	4.4	1.2	7.7	6.6	2.3	3.6	7.4	4.0	3.1	2.7	4.7	3.8	7.2	24.8	0.0	3.4	4.0	15.1	78.5
Strophanthus kombe	26.9	35.4	3.4	1.8	8.8	5.7	3.0	3.9	7.7	5.0	2.5	2.9	3.6	3.9	7.0	24.8	0.6	3.5	3.8	13.7	80.3
Vinca rosea	19.4	34.4	4.8	1.8	8.5	5.7	2.2	4.7	7.5	3.6	3.0	3.3	5.3	4.3	8.6	19.0	0.0	3.8	5.0	12.0	80.3
Asclepiadaceae																					
Asclepias tuberosa	32.5	24.1	4.8	1.3	9.4	4.7	2.3	3.8	5.9	4.5	2.6	2.6	4.2	3.7	7.1	20.6	0.9	4.0	4.0	11.7	78.9
Tubiflorae																					
Polemoniaceae																					
Cobaea scandens	18.1	22.1	5.8	1.3	5.4	4.6	3.4	3.5	6.2	3.6	2.8	4.1	4.7	4.3	8.1	15.5	2.6	3.7	4.6	10.4	73.0
Gilia americana	26.9	30.7	5.5	1.6	11.4	4.1	2.0	3.2	5.6	3.7	2.5	2.8	4.2	3.7	8.2	21.5	0.4	3.0	4.4	10.4	82.2
Polemonium caeruleum	23.8	26.1	4.4	1.4	7.6	5.5	1.7	3.8	5.3	3.1	2.2	2.6	3.7	3.7	7.2	18.1	0.5	3.2	3.4	10.1	70.5
Boraginaceae																					
Cerinthe minor	31.9	52.6	3.7	2.6	10.7	4.5	1.9	3.7	5.6	6.1	4.4	3.0	4.6	4.2	8.7	19.2	0.3	3.9	3.5	12.8	81.9
Cynoglossum nebrodense	21.9	33.6	4.6	2.5	8.0	5.0	2.3	4.5	6.8	4.5	3.4	3.9	4.9	5.3	8.3	17.3	1.0	3.4	4.5	11.9	78.8
Echium plantagineum[b]	19.4	29.9	2.9	2.2	11.5	3.8	2.1	4.0	6.1	3.8	3.2	3.4	3.7	3.2	7.9	16.0	0.7	3.5	4.0	13.8	72.2
Lappula redowskii	17.8	18.8	4.0	2.3	9.6	4.7	2.1	4.0	6.2	3.6	2.8	3.4	5.2	3.7	8.9	20.1	2.5	4.4	5.0	12.8	81.5
Onosmodium molle[b]	11.9	17.2	2.9	2.2	11.5	4.4	2.1	4.1	5.7	3.0	3.5	3.0	4.4	3.6	8.3	21.5	1.8	5.0	3.9	12.9	79.4
Verbenaceae																					
Citharexylum montevidense[c]	24.4	50.4	2.9	2.2	11.9	5.7	2.5	4.1	6.9	4.8	3.8	3.6	4.9	4.9	8.1	18.8	0.0	5.1	4.6	10.4	87.6
Clerodendrum trichotomum	25.0	60.7	3.0	2.1	11.9	5.6	2.6	4.0	6.3	4.5	4.3	3.9	5.0	4.2	8.6	18.2	0.0	3.7	4.4	9.1	84.6
Labiatae																					
Leonotis nepetaefolia	28.8	35.9	4.3	2.0	8.4	5.9	2.6	3.5	5.8	4.3	3.5	3.1	4.4	4.2	8.8	14.9	0.8	3.7	4.1	9.8	75.9
Majorana hortensis	31.3	39.7	3.2	2.6	11.8	4.9	2.4	3.4	6.0	4.7	3.8	3.1	4.7	4.9	8.3	18.0	0.3	3.5	4.7	9.5	82.9
Marrubium vulgare	25.6	36.9	4.0	1.6	6.3	8.2	3.0	3.1	5.7	4.6	5.1	3.1	4.2	4.3	10.7	13.6	0.5	3.0	4.0	8.6	70.4
Molucella laevis[b]	25.0	37.2	2.0	1.7	8.8	7.8	2.6	3.1	5.3	3.9	4.0	2.9	4.2	3.8	10.6	14.5	0.4	3.1	3.7	8.4	72.4
Monarda punctata	21.3	31.3	3.1	2.1	12.9	5.3	2.4	3.9	6.9	6.0	3.1	3.4	5.7	5.4	8.9	18.1	0.0	4.0	5.0	9.7	90.8
Physostegia virginiana[b]	25.0	35.2	3.7	1.4	9.6	4.4	2.1	3.6	6.5	3.9	3.1	3.2	4.5	4.3	8.4	17.2	1.1	3.2	4.1	10.2	76.1
Satureja hortensis[b]	24.4	41.5	3.2	1.6	9.4	5.0	2.0	3.1	5.4	4.2	3.1	2.9	4.4	4.5	7.9	15.5	0.5	3.0	4.1	8.8	72.5
Sideritis montana[b]	19.4	37.6	3.4	2.4	10.3	5.9	2.2	4.1	7.3	5.0	3.1	3.6	5.4	5.1	9.5	17.4	0.6	4.4	4.6	10.1	86.2
Teucrium creticum	36.9	52.1	2.0	1.9	10.5	6.0	1.9	4.1	6.9	5.3	4.2	3.0	5.2	4.6	8.3	20.4	0.0	4.2	4.1	9.3	79.9
Ziziphora capitata	26.3	39.4	3.6	2.7	13.4	4.9	2.6	4.1	6.6	5.2	3.2	3.4	5.3	4.8	10.1	18.2	0.0	4.1	5.2	10.1	91.5
Solanaceae																					
Nicotiana glauca	25.9	42.1	2.1	1.8	10.7	4.5	1.8	4.0	6.2	4.7	2.4	3.4	4.5	4.2	7.5	18.1	0.0	3.0	3.6	11.7	71.0

Table II. Continued

Seed Source	Protein, %	Oil, %	Lysine	Methionine	Arginine	Glycine	Histidine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Alanine	Aspartic Acid	Glutamic Acid	Hydroxyproline	Proline	Serine	%Nitrogen as Ammonia	%Nitrogen as Amino Acids
Physalis nicandroides	15.0	18.8	3.2	1.8	10.0	5.1	2.1	3.6	5.8	4.1	2.5	3.7	4.5	4.8	8.6	18.3	1.7	7.5	4.6	11.7	80.4
Scrophulariaceae																					
Bellardia trixago	30.0	31.6	3.2	1.6	11.1	5.5	2.4	4.0	5.9	4.0	3.3	3.4	4.7	4.7	8.1	20.8	0.6	3.8	4.3	15.4	84.4
Nonnea macrosperma	41.3	38.6	3.9	1.8	11.0	4.0	2.3	3.7	5.3	3.6	2.6	3.0	4.1	3.6	10.0	16.1	0.3	2.9	3.6	15.3	77.9
Martyniaceae																					
Proboscidea altheaefolia	26.3	36.2	2.0	1.7	12.7	4.5	2.3	3.3	5.7	3.5	3.6	2.9	3.9	4.1	6.9	17.2	0.8	3.0	3.0	8.9	71.8
Rubiales																					
Caprifoliaceae																					
Symphoricarpos orbiculatus	10.0	15.6	2.2	1.9	7.9	4.5	1.6	2.7	5.2	3.2	1.9	2.8	3.5	3.3	7.5	16.9	0.1	3.2	3.3	11.8	63.7
Dipsacaceae																					
Cephalaria joppica[b]	16.3	23.9	5.4	2.4	7.0	8.3	2.4	4.3	7.3	2.3	3.2	4.9	5.6	6.9	10.0	14.2	0.5	4.0	5.0	9.0	81.3
Scabiosa atropurpurea	34.8	25.4	4.1	2.0	4.4	5.9	1.3	4.2	6.8	4.0	2.8	4.4	4.9	4.8	9.6	12.5	4.4	4.8	4.9	13.6	65.9
Cucurbitales																					
Cucurbitaceae																					
Cucurbita palmeri	32.5	39.4	5.0	1.9	11.5	8.3	1.9	3.0	5.7	4.6	5.3	2.4	4.1	3.8	9.8	16.0	0.3	3.0	4.1	6.1	81.7
Luffa operculata	24.4	28.6	3.9	1.7	14.8	5.5	2.2	4.0	6.4	4.7	2.5	3.0	4.5	4.6	8.0	16.8	0.2	3.5	4.2	7.5	85.4
Campanulatae																					
Compositae																					
Artemisia dracunculus[b]	31.3	38.1	4.3	2.2	7.7	5.6	2.3	4.0	6.1	4.2	2.5	3.3	5.0	3.7	8.3	20.4	0.1	4.2	4.0	12.8	75.4
Calendula arvensis	41.3	40.6	3.4	1.8	7.9	4.9	2.6	4.1	5.8	4.0	2.5	2.9	5.1	3.5	8.8	18.5	0.0	3.7	3.7	11.7	72.7
Calendula officinalis	33.8	43.5	3.6	1.7	7.2	4.6	2.4	3.7	5.3	3.9	2.3	3.0	4.5	3.5	7.5	15.7	0.3	3.1	3.4	11.8	63.6
Chamaepeuce hispanica[b]	20.0	24.1	4.7	2.1	8.3	5.5	2.6	4.3	7.4	5.9	2.9	3.7	5.9	4.8	10.7	18.2	0.7	4.5	4.5	12.4	83.2
Chrysanthemum coronarium	33.8	44.6	4.1	2.2	7.1	5.8	2.3	4.1	6.5	4.5	2.6	3.3	5.6	4.0	8.1	22.9	0.0	3.5	4.1	12.7	74.0
Crepis foetida ssp. *rhoeadifolia*[b]	24.4	23.9	5.3	2.6	7.0	6.0	2.2	4.0	6.5	4.8	2.7	4.1	5.3	4.4	8.3	19.0	0.5	5.0	4.2	12.1	78.5
Crepis vesicaria ssp. *taraxacifolia*[b]	24.4	20.5	5.8	2.0	8.5	5.5	2.7	3.9	5.9	4.3	2.8	3.9	4.6	4.1	9.3	16.1	0.7	3.7	4.6	12.2	78.8
Echinops strigosus[b]	36.9	38.8	3.9	1.4	8.9	6.1	2.3	3.9	7.3	5.0	3.4	3.7	5.7	5.0	10.1	17.8	0.0	3.7	5.0	11.3	82.5
Gundelia tournefortii	47.5	35.3	2.4	1.6	12.3	5.0	2.3	3.0	5.2	2.2	2.5	2.9	4.6	4.0	9.2	23.0	0.0	1.1	3.2	15.9	85.4
Helianthus annuus	26.9	54.4	3.6	2.2	9.2	5.8	2.5	4.2	6.3	4.6	2.8	3.6	5.4	4.3	9.4	20.8	0.0	4.4	4.2	13.2	82.4
Machaeranthera tanacetifolia[b]	15.6	8.4	3.9	1.3	4.2	4.3	1.7	3.3	5.4	3.5	2.2	2.9	4.5	3.2	11.2	16.8	0.9	3.8	3.7	14.1	63.1
Osteospermum sinuatum	45.6	39.4	3.3	1.5	8.5	4.9	2.4	4.0	5.9	3.9	2.5	2.9	4.9	3.5	9.5	21.0	0.0	3.7	3.8	13.7	77.8
Saussurea candicans[b]	18.8	30.9	4.7	1.9	7.1	5.0	2.4	4.1	6.4	4.6	2.9	3.5	5.1	4.3	9.4	17.5	1.3	4.1	4.3	12.0	71.0
Schkuhria wrightii[b]	20.6	22.2	4.1	2.5	8.2	5.5	2.1	3.8	6.1	3.9	2.3	3.5	5.1	3.8	8.6	19.5	1.3	4.1	4.9	13.8	77.8
Simsia foetida[b]	21.9	24.5	4.3	2.6	8.6	6.2	2.5	4.6	7.2	4.8	2.6	4.2	6.0	4.5	9.5	21.5	0.9	5.3	4.5	13.5	86.9
Xanthium pennsylvanicum	41.3	37.8	3.0	1.6	9.1	4.8	2.3	4.0	5.9	5.0	2.7	2.7	4.8	3.6	8.4	22.5	0.0	4.5	4.1	12.4	77.9
Xanthium strumarium	40.0	36.8	3.1	1.6	9.6	4.8	2.4	4.1	6.2	5.8	3.0	3.0	4.8	3.9	8.7	24.8	0.0	4.1	4.3	13.0	81.7
Zaluzania discoidea[b]	32.5	26.5	4.8	2.2	7.3	5.2	2.3	4.0	6.3	4.0	2.7	3.3	5.2	4.0	8.0	18.8	0.6	5.0	4.1	12.2	75.4

[a] Underscored values are more than two standard deviations above or below mean. Protein (nitrogen × 6.25) and oil on dry basis.
[b] Sample consisted of seed plus pericarp. All others consisted of seed except those noted as seed without seed coat.
[c] Sample consisted of seed without seed coat.

Table III. Mean Analytical Results for Each Family Sampled Five Times or More

Seed Source	N[a]	Protein, %	Oil, %	Lysine	Methionine	Arginine	Glycine	Histidine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Alanine	Aspartic Acid	Glutamic Acid	Hydroxyproline	N	Proline	Serine	% Nitrogen as Ammonia
Glumiflorae																						
Gramineae	5	18.80	7.50	2.66	1.92	4.72	3.70	2.08	3.88	9.42	5.08	3.30	3.40	4.96	6.24	7.02	23.84			6.74	4.28	15.86
Liliiflorae																						
Liliaceae	6	31.52	25.43	3.85	1.90	10.85	4.33	2.02	3.27	5.10	3.65	3.00	2.88	4.73	3.65	8.52	16.92	0.77	(6)	3.50	4.07	10.42
Centrospermae																						
Chenopodiaceae	5	24.88	12.30	4.70	1.72	9.04	5.52	2.74	3.60	5.72	3.78	3.10	3.20	4.44	3.78	7.88	14.96			3.24	4.08	11.34
Rhoeadales																						
Cruciferae	92	27.34	31.48	5.20	1.52	6.84	5.17	2.36	3.60	5.95	3.72[b]	2.81[b]	3.83	4.73	4.02	7.06	15.24	1.32	(91)	5.85	3.81	13.08[b]
Rosales																						
Rosaceae	5	39.48	40.50	2.46	0.76	10.02	4.56	1.98	2.70	5.90	2.80	2.96	2.30	3.66	3.32	9.32	20.88			3.32	3.38	12.32
Leguminosae	70	36.18	6.87	5.11	1.01	8.38	4.09	2.43	3.45	6.08	3.72[c]	2.91[b]	3.04	3.90	3.51	9.15	15.52	0.20	(59)	3.77	4.22	8.92
Gerantales																						
Euphorbiaceae	10	27.75	43.73	3.47	1.96	11.15	4.52	2.26	4.11	6.08	4.34	2.53	3.27	5.44	4.33	10.37	16.21	0.26	(9)	4.07	4.66	10.05
Malvales																						
Malvaceae	9	26.80	18.14	4.57	1.49	9.44	4.91	2.48	2.97	5.42	3.92	2.77	3.10	4.06	3.86	9.27	15.20	0.16	(9)	3.26	4.27	10.41
Umbelliflorae																						
Umbelliferae	8	21.83	23.39	4.43	1.71	5.51	6.03	2.11	3.91	5.46	4.00	2.50	3.24	4.94	4.34	10.74	18.99	0.75	(6)	4.48	4.29	13.64
Tubiflorae																						
Boraginaceae	8	19.99	32.89	3.79	2.24	8.83	4.35	2.06	4.00	5.95	3.96	3.41	3.33	4.44	3.76	8.20	17.46	1.81	(7)	3.97[b]	4.34	11.86
Labiatae	12	26.33	38.57	3.39	2.02	10.08	5.70	2.43	3.68	6.27	4.73	3.63	3.26	4.80	4.60	9.13	17.03	0.42	(10)	3.58	4.55	9.64
Scrophulariaceae	5	25.26	33.64	3.78	1.58	9.48	4.72	2.16	3.94	5.92	3.84	2.94	3.40	4.58	4.42	8.66	16.16			3.64	4.42	12.40
Cucurbitales																						
Cucurbitaceae	6	30.65	40.83	4.23	1.90	12.75	5.77	2.40	3.75	6.60	4.50	3.28	2.73	4.40	4.17	8.63	16.42			3.35	4.40	7.78
Campanulatae																						
Compositae	35	31.82	32.61	3.83	1.81	8.17[b]	5.09	2.25	3.95	6.11	4.19	2.62	3.30	5.01	3.93	8.94	19.59	0.41	(28)	4.04	4.13	12.36[b]
Std. dev.		8.62	8.45	0.86	0.32	1.82	0.80	0.38	0.45	0.82	0.72	0.52	0.40	0.55	0.55	1.17	2.83	0.62		0.56	1.89	11.48
LSD (5 observations)		10.92	10.69	1.07	0.42	2.29	1.02	0.48	0.57	1.05	0.90	0.65	0.51	0.71	0.68	1.47	3.59	0.79		0.71	2.40	14.51
LSD (9 observations)		8.14	7.97	0.82	0.31	1.72	0.76	0.37	0.42	0.76	0.68	0.48	0.37	0.51	0.51	1.10	2.66	0.59		0.54	1.78	10.83

[a] N = number of samples (except hydroxyproline).
[b] Number of samples = N minus one.
[c] Number of samples = N minus two.

samples in many instances includes less than 5% of the genera in the family. As a rough measure in making family comparisons two least significant differences (LSD) are given at the end of Table III for use when each of two means being compared is based on either five or nine observations. If the difference exceeds the appropriate LSD, the means differ significantly with approximately one chance in 20 that the difference actually results from sampling variability.

Examples of relationships between plant family and composition seen in Table III are: the low lysine content of seed from Gramineae and Rosaceae; the high lysine in Cruciferae and Leguminosae; the low methionine content of Leguminosae and Rosaceae; the high arginine and glycine in Cucurbitaceae and the low amount of these amino acids found in Gramineae. Isoleucine is low in Malvaceae and Rosaceae; leucine and phenylalanine are high in Gramineae; threonine is high in Cruciferae; valine is high in Euphorbiaceae; alanine and glutamic acid are high in Gramineae; proline is high in Gramineae and Cruciferae.

Based on analyses of seeds of 54 species of Gramineae, Taira (1962a,b, 1963) found that the subfamilies Pooideae, Eragrostoideae, and Panicoideae differ from each other in their amino acid patterns and also from the subfamilies Pharoideae and Arundinoideae which have similar amino acid patterns. Seeds from the Panicoideae, which include corn and sorghum, were much higher in leucine and alanine than seed from the other subfamilies. The means for the amino acids from the 54 species were: lysine 3.40, methionine 1.76, arginine 4.40, glycine 4.00, histidine 2.10, isoleucine 4.39, leucine 9.34, phenylalanine 4.84, tyrosine 2.12, threonine 3.79, valine 5.60, alanine 6.90, aspartic acid 6.69, glutamic acid 22.1, proline 11.80, and serine 5.02. These means agree rather well with those for only five species from the Gramineae reported in Table III, except for tyrosine and proline.

The relative standard deviations of each of the amino acids in seed from 14 species of *Lesquerella* (Miller *et al.*, 1962b) were less than those for each of the amino acids from 41 species representing 29 genera of the Cruciferae (Miller *et al.*, 1962a) except for leucine, alanine, and serine. This variation is consistent with expected greater uniformity within genera than within the family. The mean for each amino acid within the genus *Lesquerella* was about the same as the mean for the 41 species from the 29 genera of the Cruciferae, except for lysine. Different varieties of *Brassica campestris* and of *B. napus* grown in different places, as indicated by analysis of four accessions from each species, showed few, if any, differences in amino acid composition among the accessions or between the species.

NONPROTEIN NITROGEN

Sources of Nitrogen Other than from Amino Acids Found in Protein. In many seed meal hydrolyzates a relatively low percentage of the nitrogen is in the amino acids of protein (see Table III, next to last column). The ammonia nitrogen probably is formed in great part from the amides of glutamic and aspartic acids. Other sources of ammonia are threonine and serine, known to be unstable to acid hydrolysis. Such unstable amino acids include less familiar amino acids from the seed of some plant species, such as albizziin (Gmelin, 1959), and probably amino acids that have not been characterized. Other sources of nitrogen are nonprotein amino acids stable to acid hydrolysis such as canavanine, which is tentatively identified from its elution position, and α,β-diaminopropionic acid, which elutes with histidine under the conditions of analysis. Others appear as unidentified elution peaks. Some may go undetected because they elute in the same position as one of the protein amino acids, and thus are erroneously calculated as part of it. Currently, of the average 10 new amino acids characterized per year according to Meister (1965), a high percentage have been isolated from plants.

In the Cruciferae and related plants, thioglucosides containing nitrogen are found (Kjaer, 1960). On acid hydrolysis the nitrogen in these compounds probably form ammonia (VanEtten *et al.*, 1963a). Recent reports show that the organic aglycon of the thioglucosides has a biogenetic source in common with the amino acids (Benn, 1965; Chisholm and Wetter, 1964).

Canavanine in the Leguminosae. Canavanine contents of seed from the Leguminosae are given in Table IV. None of these have been previously reported as containing the compound, except *Melilotus alba.* Of 70 Leguminosae analyzed in this survey, 23 contained canavanine ranging from 0.7 to 18.7 grams per 16 grams of nitrogen. The compound is present also in other Leguminosae (Bell and Tirimanna, 1965; Birdsong *et al.*, 1960).

Unidentified and Less Familiar Amino Acids. 4-Hydroxy-L-pipecolic acid has been isolated from *Acacia* seeds (Leguminosae) by Virtanen and Gmelin (1959) and from *Armeria maritima* seeds (Plumbaginaceae) by Fowden (1958). Seed from *Peganum harmala* (Zygophyllaceae) contains this amino acid in large amounts (Table V). Based on tentative identification, the compound occurs also in seed from *Calliandra eriophylla* and *Plantago ovata* of the families Leguminosae and Plantaginaceae, respectively (VanEtten *et al.*, 1963a). Isolation or tentative identification from four plant families indicates the componnd to be more widespread than other less familiar amino acids, such as those only in Leguminosae. Examples are canavanine (see above), albizziin, 2,3-diaminopropionic acid, mimosine, and willardiine in the subfamily Mimosoideae (Gmelin, 1959) and free amino acids and related compounds implicated in lathyrism (Schilling and Strong, 1955; Ressler *et al.*, 1961; Ressler, 1962). Some species from the Leguminosae, plants which commonly live symbiotically with nitrogen-fixing microorganisms, contain these less familiar amino acids and related compounds, all high in nitrogen.

Table IV. Canavanine Content of Seeds from Leguminosae

Genus and Species	Canavanine, Grams per 16 Grams Nitrogen
Abrus precatorius	0.7
Astragalus panduratus	12.9
Hedysarum fontanesii	9.6
Melilotus alba	0.7
Scorpiurus subvillosa	7.1
Vicia angustifolia	4.3
Vicia gigantea	11.3

Table V. Major Elution Peaks from Unidentified Compounds and Less Familiar Amino Acids

Genus and Species	Family	Elution	Position[a]	Amount,[b] Grams per 16 Grams Nitrogen
Abrus precatorius	Leguminosae	$R_{asp.a.}$	0.73[c]	0.6[c]
		$R_{asp.a.}$	1.03	0.1
Akebia trifoliata	Lardizabalaceae	$R_{lys.}$	1.10	0.2[d]
		$R_{meth.}$	0.99	0.1
Asphodelus microcarpus	Liliaceae	$R_{asp.a.}$	0.71	1.5
Astragalus panduratus	Leguminosae	$R_{ser.}$	1.14	0.2
Baptisia leucantha	Leguminosae	$R_{leu.}$	1.07	0.1
Cobaea scandens	Polemoniaceae	$R_{lys.}$	1.09	0.2[d]
Dalea nutans	Leguminosae	$R_{leu.}$	1.03	0.3
Dolichos lablab	Leguminosae	$R_{leu.}$	1.07	0.3
Eriogonum alatum	Polygonaceae	R_{NH_3}	1.14	0.1
		$R_{ala.}$	1.07	0.1
Hedysarium fontanesii	Leguminosae	$R_{ser.}$	1.14	0.4
Lappula redowskii	Boraginaceae	$R_{asp.a.}$	0.74[c]	3.8[e]
Lathyrus sylvestris	Leguminosae	$R_{lys.}$	1.11	6.9[f]
		R_{NH_3}	1.13	0.1
		$R_{ser.}$	1.12	0.1
Luffa operculata	Cucurbitaceae	$R_{leu.}$	1.03	0.1
Machaeranthera tanacetifolia	Compositae	$R_{asp.a.}$	0.72[c]	0.9[e]
		$R_{ser.}$	1.13	0.1
Maximowiczia sononae	Cucurbitaceae	$R_{leu.}$	1.03	0.2
Mentzelia decapetala	Loasaceae	$R_{meth.}$	0.98	0.7
		$R_{leu.}$	1.03	0.2
Peganum harmala	Zygophyllaceae	$R_{ser.}$	1.05[c]	26.8[g]
Pisum sativum var. *arvense*	Leguminosae	$R_{lys.}$	1.11	0.2[d]
Stizolobium deringeanum	Leguminosae	R_{NH_3}	1.11	0.2
		$R_{leu.}$	1.08	6.0
		$R_{phen.}$	1.11[d]	0.5
Trigonella arabica	Leguminosae	R_{NH_3}	0.94	0.1
Vinca rosea	Apocynaceae	$R_{leu.}$	1.04	1.1

[a] $R_{amino\ acid}$ = ml. of effluent of unknown peak divided by ml. of effluent of amino acid.
[b] Calculated as leucine, if absorption maxima was at 570 mμ, and as proline, if absorption maxima was at 440 mμ except for conditions described under [g] (see below).
[c] Absorption maxima at 440 mμ instead of 570 mμ.
[d] Possible identity 2,4-diaminobutyric acid.
[e] Possible identity, 3-hydroxyproline.
[f] Identified as 2,4-diaminobutyric acid (VanEtten and Miller, 1963).
[g] Identified as 4-hydroxy-L-pipecolic acid based on identical elution position as the authentic compound on ion-exchange column chromatography and paper chromatography with 1-butanol:ethanol:water 4:1:4 upper phase and also based on nitrogen content, which agreed with the theory for the compound on a small sample isolated in crystalline form. Amount present calculated from absorption color constant at 440 mμ for the pure compound.

The unidentified peak $R_{asp.a.}$ 0.72 to 0.74 with a 440-mμ maximum found in three species (Table V) could be due to 3-hydroxyproline, recently isolated from acid hydrolyzates of sponge and collagen and shown to elute in this region upon ion exchange chromatography by Irreverre *et al.* (1962). Since several sugars and related compounds containing no nitrogen pass through the column ahead of aspartic acid (Zacharius and Talley, 1962), further work is required to identify the peak.

POTENTIAL OF SEED PROTEIN FOR FOOD OR FEED

Quantity of Protein. Large amounts of protein either before or after oil extraction are in seed meals from nearly all the 379 species—e.g., Table II, columns 2 and 3. Of the species in Table II over 100 contain 25% or more seed oil. These may be good sources of both protein and oil.

For most species the amino acids in protein and ammonia, a high percentage of which likely originates from amide nitrogen (last two columns in Table II), are the source of more than 85% of the crude protein nitrogen. This basis is a more meaningful measurement of protein content, because nitrogen from other sources, if present, is not taken as a part of the crude protein. Seed from most of the species could well serve as a good source of low-cost protein if the plants could be as efficiently grown, harvested, and marketed as are our present major crops. Because of their high protein and lysine content, many are potential sources of protein concentrates to supplement cereals and starchy tubers, now major food sources especially in developing nations of the world.

Protein Quality Based on Nutritionally Essential Amino Acid Content. In Figure 1, protein quality of seed meals is gaged by comparison of their nutritionally essential amino acids with recommendations for man by FAO (1957). For comparison the amounts of essential amino acids in corn, rice, wheat, and soybeans are also shown. Of seed meals from the 379 species, more than half are nutritionally adequate in lysine. Lysine deficiency is apparently a practical problem because of the relatively small amount of this amino acid in cereals, a major source of food and feed protein. Since cystine was not accurately determined for most of the 379 species, values for this amino acid are not included in Figure 1. The requirement shown for methionine is based on the assumption that enough cystine is also present to replace a maximum amount of the methionine. Even with this optimistic method of evaluation, the mean for methionine for the 379 species and for the cereals and soybeans are all below the minimum requirement. By calculations from the lower sulfur amino acid requirement recommended by FAO (1965), rice and corn are adequate in methionine.

Isoleucine is also deficient in seeds from most of the 379 species. Soybean meal is high in this amino acid, as well as in lysine. Of the remaining amino acids, except for tyrosine, most seeds have more than adequate amounts. However, wheat is lower in threonine than the recommended requirement. In comparison with the provisional amino acid pattern, cottonseed is low in methionine and isoleucine (Carter *et al.*, 1966).

The nutritionally essential amino acid requirements for swine (NAS–NRC, 1959) are similar to those of man. Poultry requirements are higher and include arginine, glycine, and histidine as essential amino acids for optimum growth (NAS–NRC, 1960).

Protein Quality of Selected Seeds Compared with the 1965 FAO/WHO Pattern. The FAO provisional amino acid requirement for man was modified (WHO, 1965). More emphasis is now placed on the pattern of the essential amino acids. The requirement for each essential amino acid is expressed in milligrams of the amino acid per gram of the total essential amino acids in the protein source. Such a calculated pattern of the essential amino acids in whole hen's egg is used as a standard because its pattern satisfies the best estimates.

Essential amino acid patterns for a number of major seed protein sources and for *Crambe abyssinica* and *Lesquerella* seed selected from the 379 species are given in Table VI. The amino acid pattern and the high-protein content of defatted seed from *C. abyssinica* and *Lesquerella* indicate that these oil seeds should provide a good supplemental protein to use with cereal grains. The lysine content of these two Cruciferae is close to that for soybeans and the sulfur amino acids are present in larger amounts. The isoleucine content is lower. The pattern for crambe protein is much the same as that of hen's egg except that crambe meal contains less isoleucine. As in Figure 1, the high leucine content of corn is apparent, a factor which, together with the low lysine, tryptophan, isoleucine, and valine, shows the unbalanced pattern of the essential amino acids in this grain. The *opaque-2* corn under development is much improved, especially in lysine content.

From information given in Table VI and Figure 1 and from examination of the amino acid composition of seed from individual species (Table II and from earlier publications), it is apparent that nearly all have potential as a protein source for food or feed. From the 379 species examined, and from the amino acid composition of seed from 54 species of the Gramineae reported by Taira (1962a,b, 1963), it appears that in his selection of the cereal grains, man picked seed proteins of poor nutritional quality. However, because of his omnivorous nature, the cereal grains probably serve as a good supplement to animal protein.

Harmful Substances in Plant Seeds. A major problem in the use of plants as a source of food or feed is to remove or inactivate acute or cumulative toxic substances if present. Those substances that exert a delayed or cumulative effect are a greater hazard, because such effects are often hard to recognize and to relate to the cause. In a search for new plant seed as a food or feed, a major effort should be placed on detecting and removing any possible toxins. The nonprotein nitrogenous substances in the seed of many Leguminosae are known or suspected to be toxic. The thioglucosides present in the Cruciferae and related plants are the source of goitrogens (Greer, 1962). Selection of

Table VI. Essential Amino Acid Patterns[a]

A/E ratio. Milligrams per gram of total essential amino acids

Amino Acid	Hen's Egg	Corn[b]	Opaque-2[b] Corn	Low-Protein Rice[c]	Soybeans[d]	Wheat[e]	Crambe[f]	Lesquerella[g]	Safflower[h]
Lysine	125	66	117	111	157	80	140	180	98
Total sulfur-containing amino acids	107	75	82	76	74	126	126	99	98
Methionine	61	47	47	53	37	47	47	38	46
Cystine	46	28	35	23	37	79	79	61	52
Isoleucine	129	94	95	114	118	106	106	99	113
Leucine	172	328	244	223	177	205	170	159	177
Total aromatic amino acids	195	217	209	205	205	233	186	178	221
Phenylalanine	114	123	120	144	115	142	109	99	132
Tyrosine	81	94	90	61	90	91	76	79	89
Threonine	99	85	97	96	99	87	113	115	98
Tryptophan	31	17	. . .	33	30	32	33	35	27
Valine	141	118	137	142	126	130	128	135	162
E/T ratio,[i] g./g.	3.22	2.65	2.51	2.47	2.71	2.10	2.25	2.16	2.04
Crude protein, %	. . .	10.5	10.6	7.3	61.0	15.9	49.0	31.0	60.0

[a] Calculated as described by WHO (1965).
[b] From data of Mertz *et al.* (1965) except for tryptophan. Tryptophan content taken from Block and Weiss (1956).
[c] From data of Cagampang *et al.* (1966). High-protein rice gave a similar pattern, except lysine was 87 and tryosine, 85.
[d] From data of Rackis *et al.* (1961).
[e] From data of Waggle *et al.* (1967) consisting of average from nine varieties of spring and winter wheats.
[f] From data of Miller *et al.* (1962a) and VanEtten *et al.* (1961b).
[g] From mean amino acid content from seed of 14 species of *Lesquerella* (Miller *et al.*, 1962b).
[h] From data of VanEtten *et al.* (1963b).
[i] Grams of essential amino acids per gram of nitrogen in seed meal.

seed from these plant families for food or feed uses would require extraction or other ways of removing these deleterious substances if they were present in large enough amounts to be harmful.

In practice, seed meals may frequently be improved for feed or food uses by inactivation of deleterious substances by heat, mechanical separations, and selective extraction. Three examples can be cited of applications of these procedures. Inactivation of deleterious enzymes and related substances by heat has been effective in toasting soybeans to inactivate trypsin inhibitors and hemagglutinins. This method of improving the product requires careful control, since excessive heat decreases the nutritional quality of protein for monogastric animals. The available lysine- and sulfur-containing amino acids are decreased by excessive heat treatment (Liener, 1958). Often a protein concentrate can be obtained by removal of indigestible hull. Safflower, as harvested, contains 45% hull that makes it unsuited for monogastric animals. Mechanical removal of the hull and extraction of the oil give a meal containing 60% crude protein of which more than 90% of the nitrogen is present as amino acids and amide nitrogen (VanEtten *et al.*, 1963a). The removal of thioglucosides intact or as their hydrolysis products by solvent extraction gives a nontoxic meal from *Crambe abyssinica* seed (Tookey *et al.*, 1965; VanEtten *et al.*, 1966). Rats fed 28% of this meal in the ration for 90 days grew at an essentially normal rate with no evidence of toxicity based on histological examination of body organs (Tookey *et al.*, 1965). The extracted meal was higher in crude protein than the original defatted meal before solvent removal of thioglucoside products. Without extraction, about 87% of the crude protein nitrogen was derived from protein amino acids; after extraction, 97% of the crude protein was derived from protein amino acids. The amino acid pattern was essentially the same before and after extraction, as the amount of each amino acid in the crude protein was increased by the extraction due to the removal of nonprotein nitrogen.

ACKNOWLEDGMENT

The authors thank C. E. McGrew and B. R. Heaton for micro-Kjeldahl determinations; R. Gmelin of Biochemical Institute, Helsinki, Finland, for a sample of isolated 4-hydroxypipecolic acid; R. W. Miller for some of the amino acid analyses; I. Stein for many of the computations; and I. A. Wolff for encouragement and advice.

LITERATURE CITED

Altschul, A. M., "Proteins, Their Chemistry and Politics," Basic Books, New York, 1965.
Anal. Chem. **33,** 480 (1961).
Bell, E. A., Tirimanna, A. S. S., *Biochem. J.* **97,** 104 (1965).
Benn, M. H., *Can. J. Chem.* **43,** 1 (1965).
Birdsong, B. A., Alston, R., Turner, B. L., *Can. J. Botany* **38,** 500 (1960).
Block, R. J., Weiss, K. W., "Amino Acid Handbook," 1st ed., Charles C. Thomas, Springfield, Ill., 1956.
Cagampang, G. B., Cruz, L. J., Espiritu, S. G., Santiago, R. G., Juliano, B. O., *Cereal Chem.* **43,** 145 (1966).
Carter, F. L., Castillo, A. E., Frampton, V. L., Kerr, T., *Phytochem.* **5,** 1103 (1966).
Chisholm, M. D., Wetter, L. R., *Can. J. Biochem.* **42,** 1033 (1964).
Deyoe, C. W., Shellenberger, J. A., J. AGR. FOOD CHEM. **13,** 446 (1965).
Earle, F. R., Jones, Q., *Econ. Botany* **16,** 221 (1962).
Food Agr. Organ. U. N., FAO Nutr. Studies **16** (1957).
Food Agr. Organ. U. N. "Protein at the Heart of the World Food Problem," Rome, 1964.
Fowden, L., *Biochem. J.* **70,** 629 (1958).
Gmelin, R., *Hoppe-Seylers Z. Physiol. Chem.* **316,** 164 (1959).
Greer, M. A., *Recent Progr. Hormone Res.* **18,** 187 (1962).
Hamilton, H., Ed., "World Population and Food Supplies, 1980," American Society of Agronomy, Madison, Wis. *ASA Spec. Publ.* **6** (1965).
Irreverre, F., Morita, K., Robertson, A. V., Witkop, B. *Biochem. Biophys. Res. Commun.* **8,** 453 (1962).
Jones, Q., Earle, F. R., *Econ. Botany* **20,** 127 (1966).
Kjaer, A., "Modern Methods of Plant Analysis," L. Zechmeister, Ed., p. 122, Springer-Verlag, Vienna, 1960.
Liener, I. E., "Processed Plant Protein Foodstuffs," A. M. Altschul, Ed., p. 79, Academic Press, New York, 1958.
Meister, A., "Biochemistry of the Amino Acids," p. 2, Academic Press, New York, 1965.
Mertz, E. T., Vernon, O. A., Bates, L. S., Nelson, O. E., *Science* **148,** 1741 (1965).
Miller, R. W., VanEtten, C. H., McGrew, C., Wolff, I. A., Jones, Q., J. AGR. FOOD CHEM. **10,** 426 (1962a).
Miller, R. W., VanEtten, C. H., Wolff, I. A., *J. Am. Oil Chemists' Soc.* **39,** 115 (1962b).
Natl. Acad. Sci.-Natl. Res. Council, Washington, D.C., "Nutrient Requirements for Poultry," *Publ.* **827,** 7 (1960).
Natl. Acad. Sci.-Natl. Res. Council, "Nutrient Requirements for Swine," *Publ.* **648,** 12 (1959).
Rackis, J. J., Anderson, R. L., Sasame, H. A., Smith, A. K., VanEtten, C. H., J. AGR. FOOD CHEM. **9,** 409 (1961).
Ressler, C., *J. Biol. Chem.* **239,** 733 (1962).
Ressler, C., Redstone, P. A., Erenberg, R. H., *Science* **134,** 188 (1961).
Schilling, E. D., Strong, F. M., *J. Am. Chem. Soc.* **77,** 2843 (1955).
Spackman, D. H., Stein, W. H., Moore, S., *Anal. Chem.* **30,** 1190 (1958).
Taira, H., *Botan. Mag. (Tokyo)* **75,** 80 (1962a).
Taira, H., *Botan. Mag., (Tokyo)* **75,** 242 (1962b).
Taira, H., *Botan. Mag. (Tokyo)* **76,** 340 (1963).
Tookey, H. L., VanEtten, C. H., Peters, J. E., Wolff, I. A., *Cereal Chem.* **42,** 507 (1965).
VanEtten, C. H., Daxenbichler, M. E., Peters, J. E., Wolff, I. A., Booth, A. N., J. AGR. FOOD CHEM. **13,** 24 (1966).
VanEtten, C. H., Miller, R. W., *Econ. Botany* **17,** 107 (1963).
VanEtten, C. H., Miller, R. W., Earle, F. R., Wolff, I. A., Jones, Q., J. AGR. FOOD CHEM. **9,** 433 (1961a).
VanEtten, C. H., Miller, R. W., Wolff, I. A., Jones, Q., J. AGR. FOOD CHEM. **9,** 79 (1961b).
VanEtten, C. H., Miller, R. W., Wolff, I. A. Jones, Q., J. AGR. FOOD CHEM., **11,** 399 (1963a).
VanEtten, C. H., Rackis, J. J., Miller, R. W., Smith, A. K., J. AGR. FOOD CHEM. **11,** 137 (1963b).
Virtanen, A. I., Gmelin, R., *Acta Chem. Scand.* **13,** 1244 (1959).
Waggle, D. H., Lambert, M. A., Miller, G. D., Farrel, E. P., Deyoe, C. W., *Cereal Chem.* **44,** 48 (1967).
World Health Organization, "Protein Requirements," Report of a Joint FAO/WHO Expert Group, Rome, *WHO Tech. Rept. Ser.* **301** (1965).
Zacharius, R. M., Talley, E. A., *J. Chromatog.* **7,** 51 (1962).

Received for review June 23, 1967. Accepted July 16, 1967. Division of Agricultural and Food Chemistry, 153rd Meeting, ACS, Miami, Florida, April 1967. Mention of firm names or trade products does not constitute an endorsement by the USDA over other firms or similar products not mentioned.