FOOD PROTEIN EVALUATION

Amino Acid Proportions in Food Proteins Compared to Proportions Utilized in Rat Growth

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By microbiological assay the essential amino acid content of 30 foods associated with the southwestern part of the United States was determined. On the basis of the essential amino acid requirements of the rat, the following conclusions were made for the food groups analyzed. Cheese protein was fairly well balanced, except for a low proportion of methionine. Nut protein had a very high proportion of arginine and a low proportion of methionine and lysine. Fresh and dried legume proteins had a low proportion of methionine, lysine, and tryptophan. Fresh vegetable protein had a low proportion of methionine, lysine, and histidine. Methionine was deficient in all the food groups analyzed. Coconut meat required preliminary treatment to give good microbiological assay results.

Protein is a limiting factor in the diets of many peoples in many countries. Even in the United States some people receive too little protein or protein too poor in quality for good nutritional status. As the population of the United States increases, protein foods will become more and more limited, and all available sources of protein will eventually have to be utilized. A knowledge of the amount of protein in foods and their amino acid contents will then become even more important than it is now.

Publications on the amino acid contents of food proteins are numerous. But, for an accurate knowledge of the quality of proteins in foods, information on the amino acid content of many foods from many parts of the country is needed. The essential amino acid content of ten foods grown in the southwestern part of the United States was reported in previous papers from this laboratory (*6*, *8*). In the present paper the essential amino acid content of 30 additional foods, most of which were grown or produced in the southwestern part of the United States, is reported. A few foods for which only limited data on amino acids were available were also assayed.

Experimental

The foods listed in Table I were assayed for arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Most of these foods are well known and widely consumed in the United States, although several are used only in the West or Southwest. Jack cheese is typically western and is a semihard, naturally ripened, whole milk cheese. Mexican cheese is common only in the Southwest and Mexico and is consumed largely by the Spanish Americans. It is a semihard, unripened skim milk cheese with a relatively high salt and moisture content. Of the legumes, cranberry beans and garbanzos are consumed mainly in the Southwest.

The fresh vegetables were prepared for assay as described in a previous paper (*8*). The mature legumes were ground in a hammer mill and stored at room temperature. The cheeses and nuts were ground in a blender and portions of each sample stored at 0° C. for subsequent fat, ash, and moisture determinations. The remainder of the sample was extracted three times with Skellysolve B in a blender, dried at room temperature, and stored in desiccators.

Hydrolysis and microbiological assay of samples were done in the manner previously described (*6*, *8*). Horn and others (*7*) reported that hydrolyzate humin of cereals and legumes contained substances that increased microbiological response and thus caused incorrect amino acid values. These substances were removable by filtration at pH 4.0 but not at pH 7.0. With the media and procedures employed in the work reported, there were no differences in results obtained by filtration at pH 4.0 and 7.0.

Coconut required special treatment before hydrolysis to remove the major part of the soluble carbohydrates. After grinding in a blender, the coconut was dried at 60° C. and extracted in a Soxhlet extraction apparatus with Skellysolve B for 16 hours to remove fat. This fat-free sample was ground to a fine powder and stirred in water for 30 minutes. The pH was adjusted to 1.5 and 10% sodium tungstate was added slowly. The pH was readjusted to 2.7, the mixture centrifuged, and supernatant liquid decanted.

Table I. Essential Amino Acid Content of Thirty Foods

Food	Basis of Calculation	Average % Amino Acid Content									
		Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Valine
Amino Acid Content of Cheese											
Blue cheese	Fresh weight	0.537	0.558	1.07	1.75	1.35	0.540	0.963	0.749	0.292	1.61
	Protein[a]	2.75	2.86	5.51	8.98	6.92	2.77	4.94	3.84	1.49	8.23
Jack cheese	Fresh weight	0.733	0.598	1.15	1.99	1.50	0.494	1.05	0.779	0.251	1.76
	Protein	3.74	3.05	5.86	10.14	7.67	2.52	5.37	3.97	1.28	8.96
Mexican cheese	Fresh weight	1.26	0.835	1.78	2.83	2.10	0.654	1.50	1.12	0.307	2.00
	Protein	4.70	3.12	6.62	10.56	7.84	2.44	5.59	4.16	1.15	7.45
Oregon Cheddar	Fresh weight	0.932	0.744	1.54	1.80	1.97	0.668	1.59	1.04	0.307	1.89
	Protein	3.78	3.02	6.25	7.32	8.00	2.71	6.43	4.22	1.24	7.65
Swiss cheese	Fresh weight	0.970	0.918	1.66	3.03	2.16	0.685	1.51	1.08	0.346	2.14
	Protein	3.62	3.43	6.19	11.32	8.06	2.56	5.63	4.04	1.29	8.00
Tillamook	Fresh weight	1.17	0.861	1.65	2.04	2.10	0.722	1.62	1.19	0.343	2.12
	Protein	4.36	3.20	6.16	7.58	7.82	2.69	6.04	4.41	1.28	7.87
Velveeta	Fresh weight	0.533	0.458	0.874	1.49	0.977	0.413	0.798	0.625	0.160	1.17
	Protein	3.85	3.31	6.31	10.79	7.06	2.98	5.77	4.52	1.16	8.47
Amino Acid Content of Nuts											
Acorns	Fresh weight	0.615	0.213	0.479	0.690	0.541	0.118	0.404	0.370	0.107	0.613
	Protein	5.88	2.04	4.58	6.60	5.18	1.13	3.86	3.54	1.02	5.86
Almonds	Fresh weight	2.32	0.530	0.892	1.48	0.593	0.266	1.17	0.623	0.181	1.15
	Protein	10.12	2.31	3.89	6.48	2.59	1.16	5.10	2.72	0.789	5.01
Brazil nuts	Fresh weight	2.12	0.347	0.601	1.08	0.341	0.871	0.526	0.364	0.153	0.774
	Protein	13.23	2.17	3.76	6.73	2.13	5.45	3.29	2.28	0.957	4.84
Cashew nuts	Fresh weight	1.82	0.362	1.06	1.32	0.688	0.306	0.826	0.639	0.410	1.38
	Protein	9.61	1.91	5.60	6.97	3.63	1.62	4.34	3.38	2.16	7.29
Coconuts	Fresh weight	0.499	0.067	0.127	0.245	0.116	0.068	0.154	0.118	0.024	0.209
	Protein	14.59	1.96	3.71	7.16	3.39	1.99	4.50	3.45	0.702	6.11
Filberts	Fresh weight	1.66	0.266	0.552	0.784	0.295	0.146	0.457	0.362	0.242	0.723
	Protein	13.60	2.18	4.52	6.42	2.42	1.20	3.74	2.96	1.98	5.92
Pecans	Fresh weight	1.04	0.190	0.456	0.594	0.323	0.109	0.430	0.280	0.098	0.487
	Protein	11.46	2.10	5.04	6.56	3.57	1.20	4.75	3.09	1.09	5.38
Walnuts	Fresh weight	2.10	0.375	0.707	1.13	0.408	0.280	0.707	0.544	0.163	0.897
	Protein	12.98	2.29	4.33	6.94	2.50	1.72	4.33	3.33	1.00	5.50
Amino Acid Content of Mature Legumes											
Cranberry beans	Fresh weight	1.02	0.631	1.18	1.67	1.63	0.216	1.19	0.910	0.272	1.21
	Protein	5.53	3.42	6.40	9.06	8.84	1.17	6.45	4.93	1.48	6.56
Garbanzos	Fresh weight	1.93	0.559	1.09	1.59	1.36	0.375	1.46	0.791	0.155	1.35
	Protein	9.00	2.61	5.10	7.42	6.34	1.75	6.77	3.69	0.722	6.30
Kidney beans	Fresh weight	1.12	0.661	1.16	1.93	1.52	0.252	1.37	0.950	0.226	1.50
	Protein	5.32	3.14	5.51	9.17	7.22	1.20	6.51	4.52	1.07	7.13
Lentils	Fresh weight	2.27	0.620	1.16	1.88	1.43	0.201	1.12	0.940	0.202	1.58
	Protein	9.26	2.53	4.73	7.67	5.83	0.820	4.57	3.83	0.824	6.44
Lima beans	Fresh weight	1.31	0.731	1.28	1.78	1.25	0.311	1.32	1.01	0.188	1.66
	Protein	6.12	3.42	5.99	8.33	5.86	1.46	6.20	4.72	0.881	7.77
Pink beans	Fresh weight	0.957	0.667	1.17	1.63	1.22	0.210	1.22	0.945	0.220	1.17
	Protein	5.27	3.67	6.44	8.97	6.71	1.16	6.71	5.20	1.21	6.44
Split peas, green	Fresh weight	2.25	0.519	1.04	1.66	1.40	0.163	1.04	0.835	0.201	1.20
	Protein	10.67	2.46	4.93	7.87	6.64	0.773	4.93	3.96	0.953	5.69
Split peas, yellow	Fresh weight	2.10	0.477	1.00	1.59	1.41	0.159	0.991	0.805	0.189	1.16
	Protein	10.61	2.41	5.05	8.03	7.12	0.803	5.01	4.07	0.955	5.86
White beans, large	Fresh weight	1.25	0.677	1.36	1.78	1.76	0.231	1.28	0.880	0.254	1.26
	Protein	6.18	3.34	6.72	8.79	8.70	1.14	6.32	4.35	1.24	6.22
White beans, small	Fresh weight	1.14	0.581	1.28	1.66	1.12	0.220	1.33	1.05	0.265	1.25
	Protein	5.83	2.97	6.54	8.48	5.72	1.12	6.80	5.36	1.35	6.39
Amino Acid Content of Fresh Vegetables											
Fresh asparagus tips	Fresh weight	0.163	0.042	0.107	0.100	0.131	0.048	0.087	0.091	0.026	0.137
	Protein	5.44	1.41	3.59	3.34	4.40	1.61	2.92	3.04	0.864	4.59
Fresh Brussels sprouts	Fresh weight	0.266	0.100	0.188	0.180	0.179	0.046	0.160	0.130	0.033	0.173
	Protein	6.48	2.41	4.58	4.38	4.35	1.12	3.89	3.18	0.801	4.21
Fresh Lima beans	Fresh weight	0.294	0.203	0.415	0.580	0.383	0.088	0.376	0.307	0.091	0.435
	Protein	4.39	3.03	6.19	8.66	5.72	1.32	5.61	4.58	1.36	6.49
Fresh green peas	Fresh weight	0.659	0.112	0.314	0.289	0.379	0.047	0.274	0.203	0.059	0.267
	Protein	12.09	2.06	5.78	5.28	6.96	0.853	5.01	3.72	1.08	4.90
Fresh green beans	Fresh weight	0.090	0.037	0.094	0.112	0.093	0.025	0.049	0.077	0.040	0.096
	Protein	4.35	1.80	4.51	5.39	4.47	1.19	2.36	3.71	1.93	4.65
Whole egg protein (*3*)		6.6	2.4	7.7	9.2	7.0	4.0	6.3	4.3	1.5	7.2

[a] Nitrogen × 6.25.

Table II. Analyses of Food

(Per cent of fresh weight)

Food	Protein (N X 6.25)	Moisture	Fat	Ash
Cheese				
Blue cheese	19.53	47.27	24.14	5.52
Jack cheese	19.61	41.44	31.12	3.78
Mexican cheese	26.80	48.47	11.94	6.54
Oregon Cheddar	24.65	37.08	29.87	3.34
Swiss cheese	26.79	32.46	30.50	5.08
Tillamook	26.92	33.75	30.51	3.19
Velveeta	13.82	45.05	27.04	5.40
Nuts				
Acorns	10.45	4.12	33.03	3.08
Almonds	22.93	4.07	53.84	2.75
Brazil nuts	15.99	4.53	67.92	2.96
Cashew nuts	18.93	4.76	49.30	2.63
Coconuts	3.42	54.62	21.77	0.70
Filberts	12.21	7.09	63.88	2.25
Pecans	9.05	3.57	72.69	1.48
Walnuts	16.31	3.85	65.94	1.98
Mature legumes				
Cranberry beans	18.44	8.42	0.64	4.26
Garbanzos	21.46	8.00	6.02	1.96
Kidney beans	21.04	11.62	1.24	2.96
Lentils	24.52	8.64	0.68	2.66
Lima beans	21.34	9.36	1.59	3.29
Pink beans	18.17	8.70	1.70	4.10
Split peas, green	21.09	9.44	1.09	2.74
Split peas, yellow	19.79	9.40	1.04	2.78
White beans, large	20.24	8.83	1.89	3.62
White beans, small	19.57	7.14	2.00	3.94
Fresh vegetables				
Asparagus tips	2.99	91.83	...	0.68
Brussels sprouts	4.11	88.32	...	0.84
Lima beans	6.70	69.92	...	1.32
Green peas	5.45	79.14	...	0.71
Green beans	2.07	90.91	...	0.69

The solids were hydrolyzed with 20% hydrochloric acid (*6*) and the hydrolyzate was combined with the supernatant liquid. This solution of hydrolyzate and supernatant liquid was used for the microbiological assay.

Results and Discussion

The percentages of essential amino acids, calculated on the basis of fresh weight and protein content of 30 foods, are given in Table I. The percentages of proteins, moisture, fat, and ash are given in Table II. Although the amino acid composition of foods is usually expressed on a basis of per cent protein (N=16), percentages of fresh weight are also included to correspond, in part, to U. S. Department of Agriculture Handbook 8 (*17*), which lists the food components in terms of raw, processed, and prepared edible portions. This makes Table I of more value for diet preparation.

The amounts of essential amino acids in the proteins of foods do not give an accurate assessment of the nutritive value of the proteins. The proportions in which the amino acids are contained in the proteins are highly important. This has been amply demonstrated by the work of Rose (*15, 16*) on the amino acid requirements of rats; and by the work of Loosli (*10*) and Mertz, Beeson, and Jackson (*11*) on the amino acid requirements of swine. According to Albanese (*1*), the human infant up to 9 months of age requires lysine, isoleucine, and tryptophan in approximately the same proportions as Rose (*15, 16*) found for rats. Thus the nutritive values of the proteins in the foods in Table I can be better evaluated by determining the relative proportions of the ten amino acids in the proteins.

Table III compares the proportions of amino acids in the food proteins with the proportions that Rose (*15*) found to be required by the rat, and includes values for foods from a previous publication (*6*). The proportions were calculated from the analytical data by a procedure similar to one recently reported by Flodin (*4*). In this procedure the content of tryptophan because of its low value in most food proteins, is made equivalent to 1.0 and the rest of the amino acids are proportioned to it. However, tryptophan was contained in such low percentages in most of the foods that it could not logically be used as a reference acid with the value 1. Therefore, threonine was used as a reference and given a value of 2.5, which is equivalent to the proportion, as compared to tryptophan, that is required by the rat.

Included in Table I are the percentages of essential amino acids in whole egg protein, to which reference may also be made for the amounts of individual amino acids present in the foods analyzed. The use of a standard protein (whole egg) was pioneered by Mitchell and Block (*12*).

Using the proportions of amino acids (Table III) as a measure for protein quality, all the proteins in the foods reported in this paper are deficient in methionine, except Brazil nuts. Doubtless, the proteins in some of the foods contain cystine which would augment the methionine and niacin which would augment the tryptophan (*9*). As would be expected, cheese protein is fairly well balanced in all the amino acids except methionine. Nut protein is off balance, with a very high proportion of arginine, a low proportion of lysine and, except for Brazil nuts, a low proportion of methionine. The protein of both fresh and dried legumes contains low proportions of lysine, methionine, and, with the exception of snap beans, tryptophan. The fresh vegetable proteins contain low proportions of methionine, histidine, and lysine.

In another method of protein evaluation, proposed by Oser (*14*), the essential amino acids in food protein are compared to the essential amino acids in whole egg protein to obtain an essential amino acid index (EAA). From these values the biological value (BV), may be estimated. The biological values, thus obtained, are reported to correspond closely to the values obtained mainly from rat studies. In Table IV are presented the values calculated by Oser's method for the various food groups reported in this paper.

In human dietaries several food proteins are usually consumed during one meal. Therefore, a deficiency of an amino acid in one food may be offset by a more than adequate amount of the same amino acid in some other food, or the deficiency may be at least partly overcome by increasing the intake of the deficient food protein. The former method of balancing amino acid intake depends upon the assembling of a diet through the knowledge of food components and their interrelationships. The latter method has been demonstrated by Mulford and Griffith (*13*), who found that by increasing the casein content of rat diets methionine deficiency could be overcome. Almquist (*2*) has generalized the gain in efficiency obtainable by the increased intake of deficient proteins; however, Grau (*5*) has shown that

Table III. Amino Acid Proportions in Food Protein Compared to Rat Growth Requirements

	Arg.	His.	Isl.	Leu.	Lys.	Met.[a]	Pal.[a]	Thr.	Try.	Val.
Rat growth	1.0	2.0	2.5	4.0	5.0	3.0	3.5	2.5	1.0	3.5
Cheese										
Blue	1.8	1.9	3.6	5.8	4.5	1.8	3.2	2.5	1.0	5.4
Jack	2.4	1.9	3.7	6.4	4.8	1.6	3.4	2.5	0.8	5.6
Mexican	2.8	1.9	4.0	6.3	4.7	1.5	3.4	2.5	0.7	4.5
Oregon	2.2	1.8	3.7	4.3	4.7	1.6	3.8	2.5	0.7	4.5
Swiss	2.2	2.1	3.8	7.0	5.0	1.6	3.5	2.5	0.8	5.0
Tillamook	2.5	1.8	3.5	4.3	4.4	1.5	3.4	2.5	0.7	4.5
Velveeta	2.1	1.8	3.5	6.0	3.9	1.6	3.2	2.5	0.6	4.7
Average	2.3	1.9	3.7	5.7	4.6	1.6	3.4	2.5	0.8	4.9
Nuts										
Acorns	4.2	1.4	3.2	4.7	3.7	0.8	2.7	2.5	0.7	4.1
Almonds	9.3	2.1	3.6	6.0	2.4	1.1	4.7	2.5	0.7	4.6
Brazil	14.5	2.4	4.1	7.4	2.3	5.6	3.6	2.5	1.0	5.0
Cashew	7.1	1.4	4.1	5.2	2.7	1.2	3.2	2.5	1.6	5.4
Coconuts	10.6	1.4	2.7	5.2	2.5	1.4	3.3	2.5	0.5	4.4
Filberts	11.5	1.8	3.8	5.4	2.0	1.0	3.2	2.5	1.7	5.0
Peanuts, raw[b]	9.1	2.4	3.9	4.3	3.3	0.8	4.8	2.5	1.0	4.7
Peanuts, roasted[b]	8.5	2.8	4.0	4.6	3.8	0.8	4.5	2.5	1.0	4.8
Pecans	9.2	1.7	4.1	5.3	2.9	1.0	3.8	2.5	0.9	4.4
Walnuts	9.7	1.7	3.3	5.2	1.9	1.3	3.3	2.5	0.8	4.1
Average	9.4	1.9	3.7	5.3	2.8	1.5	3.7	2.5	1.0	4.7
Mature legumes										
Cranberry beans	2.8	1.7	3.2	4.6	4.5	0.6	3.3	2.5	0.8	3.3
Blackeyed peas[b]	4.0	2.0	3.0	4.9	4.0	0.8	3.2	2.5	0.6	3.6
Garbanzos	6.1	1.8	3.5	5.0	4.3	1.2	4.6	2.5	0.5	4.3
Kidney beans	2.9	1.7	3.0	5.1	4.0	0.7	3.6	2.5	0.6	3.9
Lentils	6.0	1.6	3.1	5.0	3.8	0.5	3.0	2.5	0.5	4.2
Lima beans	3.2	1.8	3.2	4.4	3.1	0.8	3.3	2.5	0.5	4.1
Pink beans	2.5	1.8	3.1	4.3	3.2	0.6	3.2	2.5	0.6	3.1
Pinto beans[b]	3.1	1.7	3.3	4.8	3.9	0.6	3.5	2.5	0.6	3.6
Split peas, green	6.7	1.6	3.1	5.0	4.2	0.5	3.1	2.5	0.6	3.6
Split peas, yellow	6.5	1.5	3.1	4.9	4.4	0.5	3.1	2.5	0.6	3.6
White beans, large	3.6	1.9	3.9	5.0	5.0	0.6	3.6	2.5	0.7	3.6
White beans, small	2.7	1.4	3.0	4.0	2.7	0.5	3.2	2.5	0.6	3.0
Average	4.2	1.7	3.2	4.8	2.9	0.7	3.4	2.5	0.6	3.6
Fresh legumes										
Blackeyed peas[b]	4.0	2.2	3.1	4.4	4.2	0.9	3.7	2.5	0.6	3.5
Lima beans	2.4	1.6	3.4	4.7	3.1	0.7	3.1	2.5	0.7	3.5
Green peas	8.1	1.4	3.9	3.5	4.7	0.6	3.4	2.5	0.7	3.3
Snap beans	2.9	1.2	3.0	3.6	3.0	0.8	1.6	2.5	1.3	3.1
Average	4.4	1.6	3.4	4.0	3.8	0.8	3.0	2.5	0.8	3.4
Fresh vegetables										
Asparagus tips	4.5	1.2	3.0	2.7	3.6	1.3	2.4	2.5	0.7	3.8
Broccoli, heads[b]	4.4	1.4	2.7	3.2	1.8	0.8	2.7	2.5	0.8	3.8
Broccoli, stalks[b]	3.5	1.2	2.5	2.9	3.3	0.9	2.4	2.5	0.7	3.7
Brussels sprouts	5.1	1.9	3.6	3.4	3.4	0.9	3.1	2.5	0.6	3.3
Potato, white[b]	3.2	0.9	2.7	3.1	3.5	0.9	3.1	2.5	0.07[c]	3.7
Spinach[b]	2.9	1.3	2.4	3.7	3.4	0.9	2.5	2.5	0.9	3.2
Sweet potato[b]	2.3	1.1	2.2	3.6	2.4	1.1	2.7	2.5	0.9	4.1
Average	4.0	1.3	2.7	3.2	3.1	1.0	2.7	2.5	0.8	3.7

[a] Cystine may in part replace methionine and tyrosine replace phenylalanine.
[b] Calculated from previous publication (*3*).
[c] Not included in average.

Table IV. Essential Amino Acid Index and Biological Values of Food Proteins[a]

	Cheese	Nuts	Mature Legumes	Fresh Legumes	Fresh Veg.	Whole Egg
EAA	86	67	80	74	70	100[b]
BV	90	70	83	76	72	106[c]

[a] Values calculated on methionine and not on methionine plus cystine.
[b] Assumed.
[c] Calculated.

at very high levels of protein intake efficiency of lysine utilization is diminished.

Summary

Thirty foods were analyzed for their essential amino acid content— seven cheeses, eight nuts, five fresh vegetables, and ten mature legumes. Values for the ten essential amino acids are presented on a basis of fresh weight and proteins. The amino acid proportions in the proteins of the foods are compared with the requirements of the growing rat.

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