Nutritive Values of Oilseed Proteins[1]

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Abstract

A protein seldom serves independently as a source of dietary amino acids—it works in concert with other proteins. Hence, the most important characteristic of each protein in the diet is its ability to fill gaps between the quantities of essential amino acids needed and those supplied by other foods. When examined from this viewpoint, oilseed proteins differ somewhat, but they all appear to be more valuable as supplementary proteins than their individual protein qualities imply. In general, feeding tests substantiate the theoretical supplementary values. Properly processed oilseed flakes, flour or concentrates of proteins prepared from them have great potential value as human food.

Introduction

Several factors must be considered in practical assessments of the suitability of a protein-containing food for dietary use. These include: digestibility of the food; composition of the digestible portion; composition and quantity of other dietary components; requirements of the consumer for nutrients (species, age, activity, state of health, individual variability); the presence of deleterious substances or characteristics (e.g., antitryptic factors of soybeans, gossypol in cottonseed, avidin in egg white, or contaminants such as aflatoxin in moldy products); social factors (superstitions, prejudice, esthetics, fads, education); and availability and cost, relative to alternate sources of nutrients. The first five topics relate mainly to the usefulness of the proteins if consumed, and the last two determine whether or not the food will be used.

Discussion

In most parts of the world diets consist of a variety of foods. The important consideration is the adequacy of the amino acids in the total digestible portion for the nutritional needs of the consumer, be it man or animal. Protein quality indices such as net protein utilization (NPU), protein efficiency ratio (PER) or biological value (BV) usually relate to diets containing a single protein, although they have equal validity when used with mixtures. They are valuable insofar as they indicate nutritional adequacy and availability for absorption, but they furnish no clues as to the probable supplementary effects if several proteins are used in mixed diets, unless the mixtures are tested biologically.

Composition data obtained chemically permit comparisons of known animal requirements with the amino acid contents of a protein or of a ration, but they do not give information regarding the biological availability of these amino acids. For intelligent evaluation of the merits of any protein, both composition and digestibility must be known for that protein and for other proteins in the diet. Fortunately, reliable data are available for most of the proteins of oil seeds and of the major dietary components they supplement (see Table I). It must be remembered that values for PER and BV vary and depend upon the quality of the sample tested.

The PER and BV data prove oilseed proteins to be adequate for growth and health of test animals. Comparisons of the amino acid requirements of animals with the composition data leads to the same conclusion. Since foods are not used independently in the diet, the pertinent question is: "How well do they work with other proteins?" The question is largely academic, as numerous experiments have conclusively demonstrated that oilseed proteins, soybean protein in particular, are excellent supplements for cereals, the probable source of other protein in low cost diets. Nevertheless, it may be well to examine some of the biological evidence of such supplementations.

In the United States the cereal used in greatest amount as food for man is wheat, largely as bread or other products baked with white flour. Hence, the supplementation of white bread with a soy protein concentrate was examined recently by Wilding et al. (16). In that research, a standard bread formula including non-fat dry milk (NFDM) was modified to include sufficient soy protein concentrate to yield 25% to 75% of the total protein. Breads baked according to these formulas were air dried and used in sufficient quantity to supply 9% protein in diets which were otherwise adequate for all nutritional needs of growing rats. These diets were fed along with 9% soy protein diets to groups of individually caged rats and gains and PER were recorded. The addition of soy protein markedly improved gains and PER, and maximum performance was reached when the soy supplied about 75% of the protein. Not all proteins added to bread are this effective. Four commercial protein breads showed PER ranging from 1.0 to 1.5, compared to 1.1 for white bread and 1.9 for a 15% soy protein bread. Others using different diets showed these supplementary effects long ago (5).

If one compares the amino acid requirements of rats with the amounts supplied by diets containing 9.09% protein as bread or soy, or by mixtures of the two, the reasons for the growth effects become obvious (Table II). In no diet are the amounts supplied adequate for optimal growth, but the 50B/50S and 25B/75S mixtures yield levels of lysine and sulfur amino acids which differ less from the requirements than either wheat or soy alone. This is reflected in the superior growth of the groups getting the 50/50 and 27/75 blends. The low percentages of the requirements for lysine and sulfur amino acids illustrate the importance of these amino acids in estimations of nutritive values. They are key indicators; when diets composed of natural components contain enough of both lysine and sulfur amino acids they seldom are seriously deficient in any other.

If the protein level of the 25B/75S diet were increased from 9% to 13.5%, there would be adequate amounts of all essentials except these two key components. They would still be 20% and 37% below the recommended amounts. Supplementation of such a diet with synthetic lysine and methionine should make it complete with respect to amino acids.

Some parts of the world rely extensively on corn

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TABLE I

Nutritional Characteristics of Proteins from Various Sources

	Corn	Rice	Wheat	White flour	Cotton-seed flour	Soy bean flour	Peanut flour	Meat and bone meal	Fish meal	Casein	Whole egg
Typical protein conc., %	8.9	7.5	11.0	11.1	50	50	50	50	65	100	47
Milligrams of Amino Acid Per Gram of Nitrogen in Product[a]											
Tryptophane	63[b]	64	72	70	74	86	69	49[b]	48	84	103
Threonine	249	233	168	164	221	246	168	222	248	269	311
Isoleucine	289	279	253	262	236	336	257	210	314	412	415
Leucine	810	513	391	439	369	482	380	383	449	632	550
Lysine	180	235	160	130	268	395	223	432	563	504	400
Sulfur AA.[c]	197	188	180	150	172	168	110	161	267	218	342
Aromatic A.A.[d]	568	511	506	508	498	508	540	334	495	678	630
Valine	319	416	270	246	308	328	311	297	391	465	464
Arginine	220	343	279	253	702	452	669	495	258	256	410
Histidine	129	100	119	114	166	149	152	101	172	190	150
Glycine	212	407	356	207	291	261	347	815	429	125	221
Essentials,[e] % total protein	48	46	38	37	48	50	46	43	51	59	60
Digestibility[f] of protein, %	80	85	92	88	90	91	94	89	92	93	......
Digestibility[g] of protein, %	94	78	91	100	90	96	97	......	......	99	100
Biological value (BV)	60	66	70	52	61	75	58	......	......	73	96
Protein EFF[h] ratio (PER)	1.2	1.7	1.5	1.0	2.0	2.3	1.7	......	2.9	2.0	3.8
Gross energy, Kcal/Kg	3918	3604	3516	3650	3560	4198	3710	3175	3360	3600	5920
Metabolizable[f] energy, Kcal/Kg	3394	3569	3379	3193	2569	2881	2920	2434	2580	2740	....
Metabolizable energy, Kcal/Kg[i]	3430	3480	3010	2640	2210	2244	....	1980	3170	....	....

[a] Amino acid values from References 10 and 14.
[b] Reference 6.
[c] Sulfur amino acids are the sum of methionine plus cystine except when values are greater for cystine than for methionine, then the sulfur amino acids are taken as twice the methionine value.
[d] Aromatic amino acids are the sum of phenylalanine plus tyrosine except when the values are greater for tyrosine than for phenylalanine, then the aromatics are taken as twice the phenylalanine values.
[e] For the purposes of this table, all amino acids listed except glycine are taken as essential, although for some ages of some species, arginine and histidine are not essential.
[f] For swine, from References 10 and 13.
[g] For rats, from Reference 7.
[h] For rats, from Reference 2.
[i] For chickens, from Reference 10.

rather than wheat as the principal cereal. The protein of corn is also not noted for its biological value, and protein deficiencies are common in populations depending on it as a major diet component. Bressani and Behar (3) showed that soy protein could serve as an efficient supplement to corn, but that peanut protein could not (Table III). Reasons for the supplementary effects of soybean protein are obvious if one calculates the extent to which the amino acids in the supplements correct the deficiencies in the corn (Table IV). This does not mean that peanuts are not a good source of protein, merely that they do not complement corn. Increasing the level of protein in a diet can make it adequate for amino acids even though the amino acid levels in the protein are not optimal. Bressani and Behar have also shown that a variety of other proteins can supplement corn. Those derived from leaves and grass may be of value (1).

Calculation of the amounts of supplementary proteins needed to meet a target pattern can be made in many ways, but we prefer a method in which supplementation is considered as a function of the energy value of the foods concerned. Such a procedure permits use of experimentally determined or calculated values for both energy and amino acids, and eliminates consideration of weight until a suitable amino acid balance has been achieved. As a practical example, consider feed for growing chickens. To simplify the illustration, we will assume that the ration supplies adequate amounts of minerals and vitamins and it includes only one cereal and one supplementary protein.

TABLE II

Amino Acids Required by Young Rats and Amounts Supplied by White Bread, Soybean Flour and Mixtures of Them

Amino acid	Amount required by the rat[a] mg/g	Amount supplied by diets containing 9.09% protein		Per cent of requirements supplied by various blends			
		From white bread mg/g	From soy flour mg/g	All bread %	All soy %	50% Bread, 50% Soy %	25% Bread, 75% Soy %
Tryptophane	1.5	0.9	1.1	60	73	67	70
Threonine	5.0	2.8	3.6	55	72	64	67
Isoleucine	5.0	4.2	4.9	84	98	91	86
Leucine	8.0	6.5	7.0	81	87	84	86
Lysine	9.0	2.2	5.7	24	63	44	53
Sulfur A.A.	6.0	2.8	2.4	48	40	44	42
Aromatic A.A.	9.0	6.9	7.4	77	82	80	81
Valine	7.0	4.2	4.7	60	67	64	66
Arginine	2.0	3.3	6.5	165	325	245	285
Histidine	3.0	1.9	2.2	63	73	68	70

[a] Requirement per gram of diet supplying 4 kcal energy per gram.

TABLE III

Influence of Various Soy/Corn or Peanut/Corn Protein Ratios on PER Values[a]

Protein supplied as soy, %	PER values for 8% total protein level	Protein supplied as peanut, %	PER values for 10% total protein level
0	1.60	0	1.55
20	2.29	33	1.48
40	2.72	45	1.52
60	2.91	55	1.50
77	2.67	76	1.61
91	2.56	82	1.46
		100	1.48

[a] *Data adapted from Reference 3.*

Table V lists the essential amino acid requirements of young chickens per 1,000 kcal of energy (12) and the amino acid contents of corn and soybean meal per 1,000 kcal. The last two columns list the supply of amino acids per 1,000 kcal as a percentage of the requirements. Thus, the natural level of protein in corn does not provide enough of any of the essentials. Since all essentials are low, the addition of pure amino acids to enrich corn to the required levels is impractical—actually the major part of the supply of essentials must come from some non-corn source.

Soybean meal provides generous quantities of the essentials, as the last column in Table V shows, and it is readily available to use with corn. Closer inspection of the data indicates that if both proteins are used, the most probable deficiencies would be lysine or the sulfur amino acids, methionine + cystine. Calculations show that all of the essential amino acids in adequate amounts can be supplied by 362 kcal from soybean meal and 638 kcal from corn, which is 45% soybean meal and 55% corn by weight and more than 30% protein in the energy part of the ration. This is a high level of protein and it provides large excesses of all amino acids except the sulfur group (Table VI). Further calculations show that a 239/761 soy/corn ratio, on a calorie basis, will provide enough of all essentials except the sulfur group, which is now suboptimal and must be brought up by the addition of 0.65 g of methionine per 1,000 kcal.

We can carry the supplementation further by decreasing the level of soy until threonine just reaches the recommended level, thus making both lysine and arginine limiting. Actually, the latter is not serious and supplementations with more methionine (0.90 g) and lysine (0.66 g) should balance the ration. This would decrease the percentage of soy in the ration from 45% to less than 20%, but at a substantial cost for expensive amino acids. The methionine needed for improving the 239 soy/761 corn ration of Table VI

TABLE IV

Extent to Which Soybean and Peanut Proteins Supplement Corn Protein

	Rat requirement[a] mg/g	Supplied by diets containing 9.09% protein			Rat requirement supplied[b]		
		From corn, mg/g	From soy, mg/g	From peanut, mg/g	From corn, %	From soy, %	From peanut, %
Tryptophane	1.5	.5	1.1	1.0	(33)	73	67
Threonine	5.0	3.6	3.6	2.4	72	72	48
Isoleucine	5.0	4.2	4.9	3.7	84	98	74
Leucine	8.0	11.7	7.0	5.5	147	87	69
Lysine	9.0	2.6	5.7	3.2	(29)	(63)	(35)
Sulfur A.A.	6.0	2.9	2.4	1.6	(48)	(40)	(27)
Aromatic A.A.	9.0	8.2	7.4	7.4	91	82	82
Valine	7.0	4.6	4.7	4.5	66	(67)	(64)
Arginine	2.0	3.2	6.5	9.7	160	325	485
Histidine	3.0	1.7	2.2	2.2	57	73	73

[a] Amino acid requirement in milligrams per gram of diet supplying 4 kcal energy/g. Reference 11.
[b] Values in ( ) indicate the three lowest percentages.

TABLE V

Relationship of Amino Acids Required by Chicks to the Amounts Supplied by Corn and Soybean Meal

	Amino acid requirements per 1000 kcal of ration[a] g	Supplied by 1000 kcal		Requirement supplied by 1000 kcal[c]	
		Of corn[b] g	Of soybean[b] g	Of corn, %	Of soybean, %
Tryptophane	0.73	0.26	3.12	(36)	426
Threonine	2.54	1.04	8.92	41	(356)
Isoleucine	2.72	1.20	12.18	44	447
Leucine	5.08	3.36	17.42	66	(343)
Lysine	4.00	0.75	14.30	(19)	(357)
Sulfur A.A.	2.72	0.82	6.08	30	(224)
Aromatic A.A.	4.72	2.36	18.40	50	390
Valine	3.08	1.33	11.87	43	395
Arginine	4.36	0.92	16.37	(21)	375
Histidine	1.45	0.54	5.40	37	370

[a] Calculated from Reference 12.
[b] Using metabolizable energy values from Table I.
[c] Values in parenthesis indicate the three or four lowest percentages.

amounts to about 1600 g or 3.5 lb./ton of mixed feed and more than most feeding tests have shown necessary.

This can be understood if we remember that the table values for the sulfur groups never exceed twice the methionine value, even though there may be more cystine than methionine in a feedstuff. For example, soybean meals contain, per gram of nitrogen, 0.111 g cystine and 0.084 g methionine, i.e., 0.027 g more cystine than methionine. The added methionine allows this extra cystine to be used efficiently. Even so, amino acid supplements are costly, as the data in the bottom lines of Table VI show. Those values are not corrected for the cystine effect. Despite the expense, supplements of pure amino acids to overcome specific deficiencies reduce feed costs under many circumstances. In practice, methionine and cystine are calculated separately for critical cost formulations.

Of course, these are overly simplified calculations; modern rations include several sources of amino acids and the cost as well as composition helps determine the relative amounts of the ingredients used. Also feedstuffs supply energy, vitamins, essential fatty acids and minerals, and all must be considered in formulating adequate rations. Obviously least-cost formulations require extensive calculations. Com-

TABLE VI

Amino Acid Compositions and Costs of Corn-Soy Based Broiler Rations Per 1000 kcal

	Amino acid requirements, g/1000 kcal	Amino acid content of corn-soy blends supplying 1000 kcal		
		638 Corn 362 Soy, g	761 Corn 239 Soy, g	809 Corn 191 Soy, g
Tryptophane	0.73	1.40	0.95	0.81
Threonine	2.54	3.89	2.91	(2.54)
Isoleucine	2.72	5.19	3.83	3.29
Leucine	5.08	8.47	6.73	6.05
Lysine	4.00	5.66	(3.99)	(3.34)
Sulfur A.A.	2.72	(2.72)	(2.07)	(1.82)
Aromatic A.A.	4.72	8.18	6.20	5.43
Valine	3.08	5.15	3.84	3.35
Arginine	4.36	6.52	4.61	(3.86)
Histidine	1.45	2.29	1.70	1.47
Added sulfur A.A.		......	0.65	0.90
Added lysine		......	......	0.66
Total wt. per 1000 kcal, g		336	322	315
Total protein per 1000 kcal, g		94.05	69.88	62.06
Soy, wt. %		45	31	20
Cost of corn and soy per 1000 kcal, ¢		2.408	2.081	1.956
Cost of amino acids added, ¢			0.092	0.303
Total cost per 1000 kcal, ¢		2.408	2.173	2.259

TABLE VII

Suitability of Various Proteins for Infant Diets

	Human milk	Whole egg	Rice	Wheat intermediate flour	Soy	Cottonseed	Peanut
Protein per 100 g food, g	1.4	12.9	7.0	12.0	47.0	51.0	52.2
Grams protein per g N	6.38	6.25	5.95	5.70	5.71	5.30	5.46
Calories per 100 g	71	163	366	365	326	325	324
Essential amino acids, grams amino acid per grams N							
Isoleucine	0.344	0.415	0.279	0.253	0.336	0.236	0.257
Leucine	0.567	0.550	0.513	0.391	0.482	0.369	0.380
Lysine	0.413	0.400	0.235	0.160	0.395	0.268	0.223
Total sulfur A.A.	0.253	0.342	0.188	0.217	0.195	0.188	0.149
Total aromatic A.A.	0.595	0.630	0.571	0.506	0.508	0.498	0.540
Threonine	0.284	0.311	0.233	0.168	0.246	0.221	0.168
Tryptophan	0.103	0.103	0.064	0.072	0.086	0.074	0.069
Valine	0.391	0.464	0.416	0.270	0.328	0.308	0.311
Total essentials	2.95	3.21	2.50	2.38	2.58	2.16	2.10
Amino acids as % of human milk pattern							
Isoleucine	100	121	81	74	98	68	75
Leucine	100	97	91	69	85	42[a]	45[a]
Lysine	100	97	57[a]	39[a]	96	65[b]	54[b]
Total sulfur A.A.	100	135	74	86	77[a]	74	59
Total aromatic A.A.	100	108	96	85	85	84	91
Threonine	100	109	82	59[b]	87	78	59
Tryptophan	100	100	62[b]	70	83[b]	72	67
Valine	100	118	106	69	84	79	80
Range		97–135	57–106	39–86	77–98	42–84	45–91
Total essentials	100	109	85	81	87	73	71

[a] First limiting amino acid.
[b] Second limiting amino acid.

puters are widely used in the feed industry to adjust formulas as ingredients vary in cost.

Although oilseed proteins have been used primarily in feeds, they are acceptable in foods and there is every reason to expect them to be used increasingly in foods. We have already mentioned the beneficial effects of soy protein when fed to rats along with wheat or corn. Because the essentials are required in similar proportions by many species, including man, this is good evidence that soy protein is an effective supplement for these two cereals. Because of the well-known shortages of food protein in widespread areas of the world, we should examine the nature of the supplementary properties of various proteins for cereals in the human diet.

Man has his most critical need for protein as an infant. In many economically or culturally depressed areas of the world, infants are weaned from their mother's milk, considered by pediatricians to be the perfect baby food, to diets in which protein is inadequate in both quantity and quality. Poor growth and poor health result, with a high incidence of serious disease and death (9). It has been repeatedly demonstrated that addition of relatively small amounts of good quality protein to such diets will prevent deficiencies and cure those that are not too far advanced or too severely complicated with infectious diseases. Thus Bressani and Behar (3) and other medical research teams have cured kwashiorkor with several mixtures of vegetable proteins as well as with animal protein. The components of these mixtures were chosen to provide assortments of amino acids which would efficiently supplement the usual dietary proteins of the children.

Oilseed proteins can play an important role in such dietary supplements. One or another of them can be produced in good yield in most climates and their composition is such that it complements the common staples. The compositional characteristics listed in Table I have been recalculated as a percentage of the human milk pattern in Table VII. From the second part of this table it is obvious that lysine, the sulfur amino acids and tryptophan are weak spots in the cereals, and to some extent in the oilseed proteins although soy has a much stronger position with respect to lysine than the other two. Thus, soy products are more efficient than cottonseed or peanut flours as supplements to lysine-poor wheat, rice and corn.

This can be seen more dramatically if we consider the amounts of amino acids present in an 800 kcal portion of the several cereals or of cereals plus supplement. This amount of energy is approximately that which an 18 lb. baby would be expected to obtain by nursing a healthy mother and it is assumed that it is optimal for growth and health. Rice alone is deficient in six essentials—seriously so (less than 70% of breast milk supply) in lysine, sulfur amino acids and tryptophan (Table VIII). Wheat alone is deficient only in lysine, 73% of the breast milk level.

In food-scarce areas there is seldom enough food, and that which is available is stretched by the addition of sugars or fruits and low-protein vegetables. If we assume that the child with an 800 cal/day requirement gets only 600 from cereals and protein supplements, the real differences in cereals and in supplements begin to show up. If all 600 kcal are from wheat, the only real deficiencies are in lysine (−465 mg) and threonine (−124 mg); leucine and valine would be about 3% lower than the desired levels. At this same energy intake, both rice and corn would have severe deficits. Thus, it is easy to understand why children in regions depending on these latter two cereals are subject to severe protein malnutrition.

It is not feasible to correct the deficiencies by feeding more cereal because excessive caloric intakes would be associated with the extra cereal. There are nutritionally sound approaches to improving protein nutrition: (a) supplement with enough good protein to make up for the deficits; (b) supplement with enough good protein to make up most of the deficits, and use amino acids to complete the diet; or (c) supplement with pure amino acids exclusively. At present this third alternative does not appear very practical except with diets in which wheat supplies almost all the calories. The 800 kcal column for wheat in Table VIII shows a deficit of 280 mg lysine per 218 g of wheat, or 1.285 g/kg. This has a value of about 0.75 cent at recent bulk prices, which does not sound like much, yet it is $6.80 per ton of wheat. Corn and rice would require more lysine and tryptophan, which is not yet commercially available. Completion of the 600 kcal portions with pure amino acids

TABLE VIII

Grams of Amino Acids Supplied by Cereals and by Human Milk

	Human milk	Rice		Wheat	
	800 kcal	800 kcal	600 kcal	800 kcal	600 kcal
Weight, g	1227	218	164	218	164
Protein, g	15.8	15.3	11.5	26.2	19.7
Nitrogen, g	2.47	2.58	1.93	4.60	3.46
Isoleucine	0.84	0.72[a]	0.54[a]	1.16	0.88
Leucine	1.40	1.32[a]	0.99[a]	1.80	1.36[a]
Lysine	1.02	0.61[a]	0.45[a]	0.74[a]	0.56[a]
Sulfur AA	0.62	0.49[a]	0.36[a]	1.00	0.75
Aromatic AA	1.47	1.47	1.10[a]	2.33	1.75
Threonine	0.70	0.60[a]	0.45[a]	0.77	0.58[a]
Tryptophane	0.25	0.17[a]	0.13[a]	0.33	0.25
Valine	0.97	1.07	0.80[a]	1.24	0.94[a]

[a] Deficient with respect to human milk.

is obviously impractical because of the number and magnitude of the deficits.

Addition of good protein food to make the diet an adequate source of all amino acids has been the customary method of correcting protein malnutrition when suitable foods have been available. Non-fat dry milk has been used successfully in a number of areas. It usually has been donated because the deficit areas seldom can afford imports. Consequently, research teams have investigated vegetable proteins that are indigenous to the areas—everything from leaves and grass to seeds—and have shown that these can be used. New techniques would be needed to produce the proteins and methods for introducing them into foods would have to be developed. Peanuts, cottonseeds, sesame and soybeans are familiar crops, and at least one of them is available in most climates. Hence, they have been used as a basis for most supplementation schemes.

These oilseed products can serve as the sole supplement to cereals, although this may not be the most efficient procedure. A blend of 9% of 50% protein soy flour with whole wheat flour will provide the required amino acids in a 600 kcal portion; 12.5% of cottonseed flour or 16% of peanut flour will do the same, greater percentages being needed because of lower lysine levels (Table IX). Larger amounts of all supplements would be needed for rice and corn, because of their lower protein levels and poorer balances of amino acids. Thus, 600 kcal blends with rice would have to contain 10.5% soy, 14.8% cottonseed or 18.8% peanut flour to meet the lysine standard. If lysine was added, smaller amounts of protein would be needed, the quantity then depending upon the second limiting amino acid. For wheat and soy this is threonine, and a blend of 4% soy in wheat will supply enough of it and all other needed amino acids except lysine, which would be short by 1.50 g/kg of blend, or by 0.15%. Table IX indicates other possible uses of pure amino acids along with vegetable proteins as supplements.

TABLE IX

Supplements to Cereals for Infants

Cereal	Per cent supplement in blend to supply 600 kcal		
	Soy	Cottonseed	Peanut
Whole wheat flour[a]	9	12	16
Lysine supplement	4 + 0.15%	4 + 0.19%	6 + 0.18%
Rice[b]	11	15	19
Lysine supplement	....	....	13 + 0.095%
Corn[b]	13	15	19
Lysine supplement	....	....	15 + 0.06%

[a] Threonine is second limiting amino acid.
[b] Tryptophan is second limiting amino acid.

Decision whether to use protein alone or protein plus amino acids involves more than cost; factors such as availability of the pure amino, facilities for accurately mixing small percentages of a powder into a blend, palatability of foods made from the blend are of equal or greater importance. Nutritionally, diets could be improved by using the cereal and supplement separately, as bread with peanut butter or as rice served along with legumes or pulses. These considerations are outside the scope of the present discussion, but we should examine costs somewhat.

Evaluation of costs is difficult because of changing ratios in prices of the several ingredients. If whole wheat is ground and blended with an oilseed flour at a local mill, the price of the blend may be quite different from that of a blend made by a mixer who purchased all his supplies.

If wheat at \$1.30 a bushel (4.8¢/kg) is mixed with 9% edible soy flour at 6.50 cwt (14.3¢/kg), both recent quotations, to meet the human milk standard with 600 kcal of blend, the ingredient cost is 5.65¢/kg. However, if lysine is available at \$2400/ton (0.265¢/g), a processor could use 4% soy flour + 0.15% lysine, and his cost would be 5.578¢/kg. The slight difference in ingredient cost (\$0.70/ton) could easily be wiped out by a decline in the cost of edible soy flour. If we use wheat at \$1.30 a bushel and solvent extracted soy flour at bulk prices of \$80./ton (8.8¢/kg) the ingredient costs for the soy/wheat blend would be considerably less than for the blend of wheat with soy and lysine; 5.16¢/kg vs 5.36c/kg.

However, if this latter blend should be more acceptable in food, the higher price might not deter its use. Under certain price structures, for example where oilseed proteins are cheaper than cereals, blends might actually cost less than cereal. Other oilseed proteins such as sesame, sunflower, safflower and linseed, have possibilities for use in human food if properly processed.

We have not stressed the importance of processing conditions or proteins separated from the various oil free flours. Either under- or over-heating decreases the nutritive value of soybean meal. PER values range from 0.65 for raw to 1.96 for optimally heated and down to 1.78 for overheated meals (15). Processing conditions are critical for best quality meals.

The proteins in concentrates from which water soluble materials have been washed or in products which have been manufactured by short, high temperature treatment retain full nutritive value (8). However isolates prepared by alkaline extractions of soybean meals followed by precipitation of the proteins at their isoelectric points have slightly lower PER values. Thus, Hackler et al. (4) found PER values for dehulled beans, dilute alkali soluble protein, proteins precipitated from alkaline solution by acid, and proteins in the whey filtered from the precipitate to be 2.51, 2.11, 2.20 and 1.93, respectively.

To summarize, the concentrations of amino acids in properly processed oilseed proteins vary from product to product. They occur in ratios such that oilseed foods tend to compensate for the deficiencies of the proteins of cereal products used with them. For optimum nutritive efficiency and minimum cost, the type of supplementary protein (and amino acids) must be matched to the cereal used. For most purposes soy protein is nutritionally superior to the other common oilseed proteins, but all can be used effectively under the proper circumstances.

REFERENCES

1. Akeson, W. R., and J. Stahmann, J. Agr. Food Chem. *13*, 145–48 (1965).
2. Block, R. J., and H. H. Mitchell, Nutr. Abstr. Rev. *16*, 249–278 (1946).
3. Bressani, R., and M. Behar, "Proceedings of the 6th International Congress of Nutrition," E. S. Livingstone Ltd., Edinburgh, 1963, p. 181–206.
4. Hackler, L. R., D. B. Hand, K. H. Steinkraus and J. P. Van Buren, J. Nutr. *80*, 205–210 (1963).
5. Harris, R. S., M. Clark and E. E. Lockhart, Arch. Biochem. *4*, 243–247 (1944).
6. Lyman, C. M., K. A. Kuiken and F. Hale, J. Agr. Food Chem. *4*, 1008–1013 (1956).
7. Mitchell, H. H., and R. J. Block, J. Biol. Chem. *163*, 599–620 *(1946)*.
8. Mustakas, G. C., and E. L. Griffin, Jr., JAOCS *41*, 607–614 (1964).
9. National Academy of Sciences—National Research Council, "Evaluation of Protein Nutrition," Publication 711, Washington, D.C., 1959.
10. Ibid. "Joint United States-Canadian Tables of Feed Composition," Publication 1232, Washington, D.C., 1964.
11. Ibid. "Nutrient Requirements of Laboratory Animals," Publication 990, Washington, D.C., 1962.
12. Ibid. "Nutrient Requirements of Poultry," Fifth Revised Edition. Publication 1394, Washington, D.C., 1966.
13. Ibid. "Nutrient Requirements of Swine," Sixth Revised Edition. Publication 1599, Washington, D.C., 1968.
14. Orr, M. L., and B. K. Watt, "Amino Acid Content of Foods. Home Economics Report No. 4," Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. (1957).
15. Simon, M., and D. Melnick, Cereal Chem. *27*, 114–126 (1950).
16. Wilding, M. D., D. E. Alden and E. E. Rice, Cereal Chem. *45*, 254–259 (1968).

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