Essential Amino Acid Content of Farm Feeds

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One hundred and fifteen different feed ingredients and related products were analyzed for each of the 10 essential amino acids. The classes of materials include the following: algae (used as feed ingredients in England), animal by-products, fermentation feeds, fish by-products, grains, grain by-products from milling and processing, oilseed residues, peas, and beans. The determinations were made by the use of microbiological assay procedures which have been studied and improved by the authors over a period of years. Amino acid content of feed ingredients has become an important factor in modern concepts and practice in feed formulation for poultry and swine.

Samples of farm feeds have been analyzed for the 10 essential amino acids at the Texas Agricultural Experiment Station during the course of a number of years. Various modifications of microbiological assay procedures have been checked one against the other. A number of sources of error have been discovered and the methods have been selected and improved accordingly.

This communication reports the amino acid composition of farm feeds as determined by the procedures which have proved most reliable in this laboratory.

In addition to the amino acids studied in this investigation, cystine, tyrosine, and glycine are of nutritional significance in farm feeds. Cystine is important because more methionine is required in its absence and a similar relationship exists between tyrosine and phenylalanine. Glycine is necessary for the rapid growth of chicks. Work is in progress in the authors' laboratory on the content of these three amino acids in farm feeds.

Experimental

Hydrolysis of Samples

For the determination of all the amino acids except tryptophan, 2 grams of feedstuff were boiled under a reflux condenser with 200 ml. of 6*N* hydrochloric acid for 24 hours. Most of the hydrochloric acid was removed by vacuum distillation. Fifty to 75 ml. of water were added to the remaining thick paste and the solution was neutralized, diluted to a suitable volume, and filtered. Samples with high fat content, such as the oil seeds, were extracted with petroleum ether before hydrolysis. Tests showed that this step was not necessary with samples of moderate fat content.

For the determination of tryptophan, hydrolysis was carried out by autoclaving with 4*N* sodium hydroxide for 16 hours at 15-pound pressure. Cysteine was used for the stabilization of tryptophan as described by Kuiken, Lyman, and Hale (*10*).

Microbiological Assay

Assay Organisms. *Lactobacillus arabinosus* 17-5 (ATCC No. 8014) was used for the determination of valine, leucine, and isoleucine; *Streptococcus lactis* R (ATCC No. 8043) for threonine, histidine, and tryptophan; *Leuconostoc mesenteroides* P-60 (ATCC No. 8042) for arginine, phenylalanine, lysine, and methionine. The organisms were maintained by weekly transfers as stabs in solid medium containing the following ingredients: peptonized milk, 1%; tryptone, 1%; filtered tomato juice, 200 ml. per liter of medium; agar, 1%. Washed cells from 18-hour cultures grown in a liquid medium of the same composition as above (except for the omission of agar) were used to inoculate the assays.

Culture Media. The basal medium used for the determination of valine, leucine, and isoleucine was the same as that described by Kuiken and coworkers (*11*) with the following exceptions: The tomato juice eluate was omitted and pyridoxine was replaced with 0.4 mg. of pyridoxamine per liter of double-strength medium. The medium used for the determination of histidine and threonine with *Streptococcus lactis* R was the same as previously reported (*13*). The hydrogen peroxide-treated peptone medium of Lyman and coworkers (*16*) was used for the determination of methionine (*15*). The medium used for the determination of tryptophan has been previously described (*9*). The medium for the determination of arginine, phenylalanine, and lysine is given in Table I.

Assay Procedure. A constant temperature water bath at 37.5° C. was used for the incubation of all organisms and the assays—using incubation periods

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of 3 days for *Lactobacillus arabinosus* and *Streptococcus lactis*, and 4 days for *Leuconostoc mesenteroides*. Response to graded increments of each sample and to the amino acid standard was determined by titration of the lactic acid produced in each tube, with 0.1*N* sodium hydroxide. Bromothymol blue was used as an indicator.

Amino Acid Standards. L-Arginine; L-histidine; L-isoleucine (allo-free); L-leucine; L-lysine.HCl (× 0.800 = L-lysine); DL-methionine; DL-phenylalanine; DL-threonine; DL-valine; DL-tryptophan.

With the assay organisms used in this investigation and with the media as indicated, the D isomers of phenylalanine, threonine, and valine are completely inactive. Therefore the weight of the DL standard is divided by two when plotting the standard curves. DL-Isoleucine and DL-leucine proved to be unsatisfactory standards because of the partial activity of the D forms. This activity of the D forms varies with the composition of the medium, particularly with respect to the content of pyridoxine and its derivatives. In the case of tryptophan, the L-tryptophan in the samples is racemized during hydrolysis with sodium hydroxide. Therefore a DL standard is used directly without dividing by two.

Useful Range of Standard Curves. L-Arginine, L-histidine, L-isoleucine, L-leucine, DL-methionine, and DL-phenylalanine 0 to 0.055 mg. per tube. L-Lysine, DL-threonine, and DL-valine, 0 to 0.11 mg. per tube. DL-Tryptophan 0 to 0.022 mg. per tube. Further details of the procedures have been described (*9–11, 13, 15*).

Table I. Basal Medium for Determination of Arginine, Phenylalanine, and Lysine with *Leuconostoc Mesenteroides* P-60[a]

	G.		Mg.
Glucose	40	DL-Alanine	2000
Sodium acetate (anhydrous)	24	L-Arginine	400
Ammonium chloride	12	DL-Asparagine	4000
		L-Cystine	400
	Mg.	L-Glutamic acid	800
Adenine sulfate	24	Glycine	200
Guanine	24	L-Histidine	200
Uracil	24	DL-Isoleucine	400
Thiamine chloride	2	DL-Leucine	400
Pyridoxine	3.2	L-Lysine	400
Calcium pantothenate	4	DL-Methionine	200
Riboflavin	4	DL-Phenylalanine	200
Niacin	4	L-Proline	200
		DL-Serine	200
	γ	DL-Threonine	100
Biotin	10	L-Tyrosine	200
p-Aminobenzoic acid	2	DL-Tryptophan	200
Folic acid	8	DL-Valine	400
	Ml.		
Salts 1[b]	20		
Salts 2[c]	10		
Salts 3[d]	10		

Adjust pH to 6.8, dilute to 1 liter with distilled water.

[a] Double strength medium for 200 tubes of 10 ml. final volume (5 ml. above medium per tube). The amino acid for which the assay is conducted is omitted from the basal medium.
[b] Salt Solution 1, K_2HPO_4, 25 g.; KH_2PO_4, 25 g.; water to 250 ml.
[c] Salt solution 2, $MgSO_4.7H_2O$, 10.0 g.; NaCl, 0.5 g.; $MnSO_4.H_2O$, 0.4 g., water to 250 ml.
[d] Salt solution 3, $FeSO_4.7H_2O$, 0.5 g.; 5 drops of concentrated hydrochloric acid, water to 250 ml.

Results and Discussion

The results of the analyses of the different kinds of feedstuffs for the 10 essential amino acids are given in Table II. In many cases a number of samples of the same material were analyzed. In the interest of saving space, only data on the sample which appeared to be most typical and representative of the product are included in the table.

For the purpose of calculating rations which contain given amounts of amino acids, the content of amino acids in the samples is given. When the objective is to compare the quantitative distribution of the amino acids in the protein of different kinds of materials, it is necessary to express the data on a constant nitrogen basis. This is frequently done by calculating to 16% nitrogen, which amounts to the same as expressing the data as per cent of the crude protein. It is true that all proteins do not contain exactly 16% nitrogen, but as more exact figures have not been established in all cases and uniformity of treatment seems desirable, the authors have chosen to use the factor 6.25 for all samples.

The amino acid requirements of animals may be expressed in several ways, one of the most satisfactory of which is to express the requirement as a percentage of the total protein in the diet. Requirements given in this way may be compared directly with the data reported in Table II to determine the adequacy or inadequacy of the amino acid distribution in a given product.

The following discussion deals primarily with the three amino acids which are most likely to be deficient in rations for swine and poultry—lysine, methionine, and tryptophan.

The requirement of the young pig for lysine is 5.5 to 5.7% of the protein, according to the report of Brinegar and coworkers (*3*). The calculated value for the lysine requirement of the chick based on the reports of Almquist and Mecchi (*1*) and Grau, Kratzer, and Asmundson (*6*) is 4.5% of the protein in a 20% protein diet.

Becker and coworkers (*2*) have shown that the minimum requirement of young pigs for tryptophan, in the presence of adequate nicotinic acid, is 0.115% of a diet containing 15.3% protein. This is 0.75% of the protein. The chick requirement calculated from the recommendation of the National Research Council (*18*) is 1.00% of the protein (20% protein diet).

The report of Curtin and coworkers (*5*) shows that the minimal methionine requirement for young pigs is 1.4% of the protein, provided that the ration contains cystine in an amount not less than 1.7% of the total protein.

According to the recommendations of the National Research Council (*18*) a 20% protein chick diet should contain not less than 0.45% methionine—2.25% of the protein. More methionine is required if the ratio contains less than 0.35% cystine. The council has also reported the composition of concentrate by-product feeding stuffs (*17*).

Algae. Of interest concerning the amino acid composition of the algae studied in this investigation is the high lysine content of *Rhodymenia palmata*. Analysis of a second sample of this material confirmed the value reported in the table. Very few plant materials which might be used as protein supplements to grain rations are high enough in lysine to compensate for the marked lysine deficiency in grains. Meals made from algae are sold in England. *Rhodymenia palmata* would seem to have possibilities as a protein supplement.

As a group, the algae studied contain adequate amounts of tryptophan but appear to be somewhat deficient in methionine, particularly for chicks.

Animal By-Products. With few exceptions, the by-products of animal origin are excellent sources of lysine. Dried skim milk and dried buttermilk are outstanding sources of methionine. The decided tryptophan deficiency of meat scraps, meat and bone scraps, and to a lesser extent of tankage, should prompt the use of supplements high in tryptophan with these products. The

Table II. Amino Acid Content of Farm Feeds

Product	Crude Protein, G. per 100 G. Product	Arginine, % Sample	Arginine, % Crude protein	Histidine, % Sample	Histidine, % Crude protein	Isoleucine, % Sample	Isoleucine, % Crude protein	Leucine, % Sample	Leucine, % Crude protein	Lysine, % Sample	Lysine, % Crude protein	Methionine, % Sample	Methionine, % Crude protein	Phenylalanine, % Sample	Phenylalanine, % Crude protein	Threonine, % Sample	Threonine, % Crude protein	Tryptophan, % Sample	Tryptophan, % Crude protein	Valine, % Sample	Valine, % Crude protein
Algae																					
Ascomeal	5.75	0.23	4.00	0.064	1.11	0.25	4.35	0.35	6.09	0.29	5.04	0.10	1.74	0.28	4.87	0.26	4.52	0.074	1.29	0.31	5.46
Cladophora rupestris	27.22	1.44	5.29	0.29	1.07	0.94	3.45	1.41	5.18	1.55	5.69	0.43	1.58	0.96	3.53	1.17	4.30	0.31	1.14	1.23	4.52
Laminaria cloustoni	10.91	0.25	2.31	0.14	1.28	0.28	2.57	0.39	3.57	0.39	3.57	0.15	1.37	0.29	2.66	0.44	4.03	0.09	0.83	0.47	4.30
Neptune's Bounty	6.01	0.15	2.50	0.052	0.87	0.19	3.16	0.27	4.49	0.178	2.96	0.075	1.25	0.21	3.49	0.20	3.33	0.063	1.05	0.24	4.06
Rhodymenia palmata	20.69	1.08	5.22	0.33	1.59	0.88	4.25	1.12	5.41	1.49	7.20	0.37	1.79	0.81	3.91	0.89	4.30	0.27	1.30	1.25	6.04
Animal By-Products																					
Blood meal	80.50	3.37	4.18	4.25	5.28	0.99	1.23	11.10	13.80	3.87	4.81	1.28	1.59	5.80	7.22	4.34	5.39	1.17	1.45	7.76	9.64
Bone meal	23.42	1.77	7.56	0.19	0.81	0.46	1.96	0.97	4.14	0.88	3.76	0.18	0.77	0.56	2.39	0.58	2.48	0.05	0.21	0.72	3.07
Dried buttermilk	30.73	1.06	3.45	0.75	2.44	1.73	5.63	3.01	9.79	2.11	6.86	0.76	2.47	1.44	4.68	1.37	4.46	0.47	1.53	2.11	6.86
Dried cheese whey	12.78	0.32	2.50	0.20	1.56	0.74	5.79	1.14	8.92	1.07	8.37	0.25	1.96	0.36	2.82	0.83	6.50	0.22	1.72	0.73	5.71
Dried skim milk	33.44	1.08	3.23	0.78	2.33	2.00	5.98	3.09	9.23	2.11	6.31	0.91	2.72	1.73	5.17	1.63	4.87	0.48	1.43	2.29	6.84
Dried whey	12.10	0.24	1.98	0.15	1.24	0.74	6.11	1.10	9.09	0.62	5.12	0.18	1.49	0.29	2.40	0.73	6.03	0.25	2.07	0.67	5.54
Meat and bone scraps	52.37	3.79	7.24	0.91	1.74	1.76	3.36	3.27	6.24	2.87	5.48	0.70	1.34	1.79	3.42	1.72	3.28	0.36	0.69	2.50	4.77
Meat scraps																					
Sample 1	45.34	3.38	7.46	0.81	1.79	1.48	3.26	2.96	6.53	2.49	5.49	0.64	1.41	1.73	3.82	1.64	3.62	0.33	0.73	2.38	5.25
Sample 2	48.41	3.36	6.94	0.74	1.53	1.50	3.10	3.04	6.28	2.68	5.54	0.66	1.36	1.64	3.39	1.53	3.16	0.32	0.66	2.17	4.48
Tankage	61.02	1.40	2.29	2.05	3.36	1.40	2.29	5.74	9.40	4.40	7.21	0.76	1.24	0.78	1.28	2.00	3.28	0.61	1.00	4.18	6.85
Fermentation Feeds																					
Dried brewer's and distiller's grains																					
Brewer's dried grains	32.63	1.59	4.87	0.81	2.48	1.66	5.09	3.12	9.56	1.33	4.08	0.65	1.99	1.75	5.36	1.29	3.95	0.37	1.12	1.94	5.95
Distiller's dried grains	26.09	1.09	4.18	0.66	2.53	1.14	4.37	3.14	12.03	0.83	3.18	0.56	2.15	1.14	4.37	0.99	3.79	0.23	0.88	1.52	5.83
Distiller's dried grains with solubles	29.50	1.04	3.53	0.73	2.47	1.19	4.03	2.91	9.86	0.98	3.31	0.64	2.17	1.33	4.51	1.02	3.46	0.24	0.81	1.51	5.12
Corn distiller's dried grains, Distiller's Feed Research Council, composite sample	25.77	1.08	4.19	0.61	2.37	0.94	3.65	2.29	8.89	0.80	3.11	0.49	1.90	1.03	4.00	0.88	3.41	0.22	0.85	1.19	4.62
Corn distiller's dried grains with solubles, Distiller's Feed Research Council, composite sample	27.82	1.12	4.03	0.75	2.70	1.17	4.21	2.95	10.60	0.75	2.70	0.60	2.16	1.26	4.53	1.08	3.88	0.23	0.83	1.47	5.28
Dried fermentation solubles																					
Distiller's solubles	27.03	0.96	3.55	0.64	2.37	0.97	3.59	1.61	5.96	0.67	2.48	0.48	1.78	1.00	3.70	0.90	3.33	0.22	0.81	1.18	4.37
Corn distiller's solubles, Distiller's Feed Research Council, composite sample	27.72	1.19	4.29	0.67	2.42	1.13	4.08	2.42	8.73	0.90	3.25	0.55	1.98	1.26	4.55	1.09	3.93	0.25	0.90	1.46	5.27
Corn butyl fermentation solubles	32.13	0.92	2.86	0.52	1.62	1.34	4.17	2.72	8.47	1.51	4.70	0.49	1.53	1.12	3.49	1.23	3.83	0.24	0.75	1.35	4.20
Cane syrup butyl fermentation solubles	25.13	0.47	1.87	0.26	1.03	1.13	4.50	1.30	5.17	0.95	3.76	0.41	1.63	0.72	2.87	0.97	3.86	0.19	0.77	1.21	4.81
Molasses ethyl fermentation solubles (Vacatone 40)	7.85	0.041	0.52	0.037	0.47	0.12	1.53	0.15	1.91	0.074	0.94	0.057	0.73	0.11	1.40	0.14	1.79	0.03	0.38	0.18	2.29
Malt sprouts	29.01	1.25	4.31	0.53	1.83	1.09	3.76	1.64	5.65	1.36	4.69	0.39	1.34	0.91	3.14	1.01	3.48	0.41	1.41	1.46	5.03
Distatic barley malt	12.28	0.65	5.29	0.29	2.36	0.52	4.23	0.81	6.60	0.49	3.99	0.18	1.46	0.62	5.05	0.43	3.50	0.22	1.79	0.70	5.70
Yeast, Fleishmann's, irradiated, dry	47.38	2.46	5.19	1.00	2.11	2.94	6.20	3.56	7.51	3.70	7.81	1.00	2.11	2.77	5.85	2.41	5.21	0.73	1.54	3.06	6.46

Fish By-Products																					
Crab bran	40.05	2.21	5.52	0.80	2.00	1.75	4.37	2.59	6.47	1.85	4.62	0.73	1.82	1.70	4.25	1.54	3.84	0.45	1.12	2.00	4.99
Fish press water	59.72	2.17	3.63	2.02	3.38	0.99	1.66	1.87	3.13	2.40	4.02	0.80	1.34	0.96	1.61	0.10	0.167	0.17	0.28		
Herring meal	72.25	4.13	5.72	1.71	2.37	4.15	5.74	5.89	8.15	5.92	8.19	2.11	2.92	2.92	4.04	3.26	4.51	1.12	1.55	4.37	6.05
Perch meal	58.42	3.64	6.23	1.14	1.95	2.69	4.60	4.08	6.98	4.39	7.52	1.61	2.76	2.22	3.80	2.46	4.21	0.70	1.20	2.56	4.38
Sardine meal	68.25	4.02	5.89	1.80	2.64	3.48	5.10	5.33	7.81	5.86	8.58	2.04	2.99	2.92	4.28	3.04	4.45	0.89	1.30	4.07	5.96
Shrimp bran	33.44	1.79	5.35	0.67	2.00	1.23	3.68	1.97	5.89	1.48	4.42	0.62	1.85	1.33	3.98	1.34	4.01	0.37	1.11	1.62	4.84
Shrimp meal	42.28	2.25	5.32	0.70	1.66	1.58	3.74	2.27	5.37	2.02	4.78	0.72	1.70	1.55	3.66	1.47	3.48	0.39	0.92	1.98	4.68
Whale meal	53.02	2.50	4.72	1.19	2.24	2.73	5.15	4.29	8.09	3.49	6.56	1.01	1.90	2.07	3.90	1.64	3.09	0.82	1.55	2.82	5.32
White fish meal	67 38	4.38	6.50	1.24	1.84	2.78	4.12	4.48	6.65	4.57	6.78	1.75	2.60	2.26	3.35	2.76	4.10	0.68	1.01	3.03	4.50
Grains																					
Barley, Cordona	13.93	0.59	4.24	0.33	2.37	0.57	4.09	0.95	6.82	0.48	3.45	0.20	1.44	0.77	5.53	0.48	3.45	0.178	1.28	0.76	5.45
Barley, Goliad	13.97	0.67	4.80	0.35	2.51	0.52	3.72	0.86	6.16	0.51	3.65	0.18	1.29	0.67	4.80	0.47	3.36	0.177	1.27	0.70	5.01
Buckwheat	11.86	1.13	9.53	0.26	2.19	0.41	3.46	0.62	5.23	0.66	5.56	0.22	1.85	0.45	3.79	0.50	4.22	0.200	1.68	0.56	4.72
Corn, Country Gentleman	11.08	0.45	4.06	0.29	2.62	0.48	4.32	1.55	13.99	0.33	2.98	0.21	1.90	0.55	4.97	0.39	3.52	0.089	0.80	0.59	5.32
Corn, yellow	8.05	0.37	4.60	0.22	2.73	0.33	4.10	0.95	11.80	0.27	3.35	0.18	2.24	0.42	5.22	0.31	3.85	0.087	1.17	0.43	5.34
Darso	8.90	0.36	4.05	0.17	1.91	0.46	5.18	1.30	14.60	0.19	2.14	0.13	1.46	0.51	5.73	0.34	3.82	0.122	1.37	0.51	5.73
Feterita	12.05	0.47	3.90	0.25	2.07	0.62	5.14	1.86	15.40	0.23	1.91	0.19	1.58	0.72	5.98	0.47	3.90	0.159	1.32	0.71	5.89
Hegari	9.94	0.32	3.22	0.19	1.91	0.49	4.94	1.45	14.60	0.17	1.71	0.14	1.41	0.55	5.53	0.37	3.72	0.122	1.23	0.56	5.63
Kafir	11.59	0.44	3.80	0.26	2.24	0.59	5.09	1.75	15.10	0.25	2.16	0.21	1.81	0.66	5.70	0.46	3.97	0.150	1.30	0.66	5.69
Millet, Hog (Proso)	12.14	0.35	2.89	0.23	1.90	0.49	4.04	1.23	10.13	0.25	2.06	0.30	2.47	0.59	4.86	0.44	3.63	0.168	1.38	0.62	5.12
Milo, Martin	10.25	0.45	4.39	0.22	2.15	0.46	4.49	1.22	11.90	0.24	2.34	0.18	1.75	0.50	4.88	0.41	4.00	0.140	1.36	0.58	5.66
Oats, Alamo	12.15	0.87	7.16	0.26	2.14	0.55	4.53	0.85	7.00	0.53	4.36	0.16	1.32	0.59	4.86	0.47	3.87	0.173	1.42	0.70	5.76
Oats, Fultex	8.98	0.64	7.10	0.19	2.11	0.39	4.33	0.63	7.01	0.43	4.78	0.14	1.56	0.44	4.90	0.36	4.00	0.103	1.15	0.53	5.89
Oats, Mustang	11.60	0.57	4.91	0.20	1.72	0.45	3.88	0.74	6.38	0.38	3.28	0.10	0.83	0.51	4.40	0.38	3.28	0.156	1.34	0.60	5.17
Oats, Ranger	10.45	0.74	7.08	0.20	1.91	0.46	4.40	0.72	6.89	0.41	3.92	0.12	1.15	0.53	5.07	0.39	3.72	0.155	1.48	0.61	5.84
Rice, Early prolific	6.39	0.54	8.44	0.14	2.19	0.28	4.38	0.51	7.98	0.28	4.38	0.14	2.19	0.31	4.85	0.22	3.44	0.098	1.53	0.40	6.26
Rice, Texas Patna	7.84	0.65	8.29	0.18	2.30	0.36	4.59	0.62	7.91	0.31	3.96	0.18	2.30	0.38	4.87	0.28	3.57	0.125	1.59	0.50	6.38
Rice, Texas Patna, Polished	7.88	0.65	8.25	0.19	2.41	0.35	4.44	0.63	7.99	0.26	3.30	0.20	2.54	0.36	4.57	0.27	3.43	0.125	1.59	0.50	6.34
Rye	11.19	0.59	5.27	0.25	2.23	0.43	3.84	0.67	5.99	0.45	4.02	0.18	1.61	0.47	4.20	0.37	3.31	0.140	1.25	0.56	5.00
Shallu	8.23	0.34	4.13	0.19	2.31	0.40	4.87	1.04	12.70	0.20	2.43	0.15	1.82	0.43	5.23	0.33	4.01	0.101	1.23	0.46	5.59
Speltz	9.56	0.46	4.81	0.20	2.09	0.42	4.39	0.67	7.01	0.29	3.03	0.16	1.67	0.46	4.81	0.38	3.97	0.122	1.28	0.47	4.92
Wheat, Austin	11.15	0.55	4.93	0.26	2.33	0.44	6.91	0.80	7.17	0.32	2.87	0.17	1.52	0.57	5.11	0.42	3.77	0.180	1.61	0.52	4.66
Wheat, Frisco	15.28	0.81	5.30	0.38	2.49	0.61	3.99	0.96	6.28	0.41	2.68	0.19	1.24	0.72	4.71	0.45	2.95	0.241	1.58	0.69	4.52
Wheat, Quanah	18.16	0.86	4.74	0.44	2.42	0.77	4.24	1.21	6.66	0.50	2.75	0.24	1.32	0.88	4.85	0.46	2.53	0.230	1.27	0.71	3.91
Wheat, Seabreeze	18.50	1.01	5.46	0.50	2.70	0.71	3.84	1.13	6.11	0.50	2.70	0.23	1.24	0.90	4.86	0.53	2.86	0.224	1.21	0.85	4.61
Wheat, Selkirk	17.00	0.83	4.88	0.48	2.82	0.60	3.53	1.05	6.18	0.43	2.53	0.22	1.29	0.86	5.06	0.52	3.06	0.249	1.46	0.78	4.59
Grain By-Products from Milling and Processing																					
Corn by-products																					
Corn meal, yellow	9.34	0.45	4.82	0.24	2.57	0.36	3.85	1.12	12.00	0.29	3.10	0.21	2.25	0.41	4.39	0.34	3.64	0.082	0.90	0.50	5.36
Corn gluten meal	45.72	1.50	3.28	1.00	2.19	2.03	4.44	7.53	16.47	0.96	2.10	1.22	2.67	2.80	6.12	1.63	3.56	0.24	0.52	2.37	5.18
Corn gluten feed	22.86	0.98	4.29	0.69	3.02	0.81	3.54	2.34	10.23	0.74	3.24	0.48	2.10	0.87	3.80	0.81	3.54	0.16	0.70	1.26	5.51
Corn oil cake meal (germ meal)																					
Sample 1	22.16	1.39	6.27	0.67	3.02	0.86	3.88	1.82	8.21	1.05	4.74	0.44	1.98	0.91	4.11	0.86	3.88	0.23	1.04	1.31	5.91
Sample 2	22.69	1.51	6.65	0.78	3.44	0.96	4.23	1.97	8.68	1.19	5.24	0.43	1.90	0.95	4.19	0.94	4.14	0.29	1.28	1.50	6.61
Hominy, yellow	10.56	0.61	5.78	0.29	2.75	0.43	4.07	1.17	11.08	0.46	4.36	0.20	1.89	0.48	4.54	0.43	4.07	0.12	1.14	0.60	5.68
Grain sorghum by-products																					
Grain sorghum oil cake meal (germ meal)																					
Sample 1	21.62	1.48	6.84	0.73	3.38	0.98	4.53	1.88	8.70	0.86	3.98	0.35	1.62	1.00	4.62	0.74	3.42	0.22	1.02	1.44	6.66
Sample 2	18.50	1.05	5.68	0.64	3.46	0.78	4.22	1.45	7.84	0.71	3.82	0.29	1.57	0.75	4.03	0.77	4.15	0.21	1.16	1.15	6.22
Grain sorghum gluten feed	22.26	0.95	4.27	0.61	2.74	0.98	4.40	2.53	11.37	0.67	3.01	0.37	1.66	1.02	4.58	0.80	3.59	0.19	0.85	1.29	5.80
Grain sorghum gluten meal																					
Sample 1	44.54	1.19	2.67	0.81	1.82	2.26	5.07	7.30	16.39	0.59	1.32	0.72	1.62	2.58	5.79	1.34	3.01	0.45	1.01	2.52	5.66
Sample 2	64.69	1.38	2.13	1.09	1.68	3.28	5.07	11.11	17.17	0.70	1.08	0.97	1.50	3.64	5.63	1.97	3.05	0.76	1.17	2.45	3.79
Milo heavy steep water 54.7% solids	17.82	1.58	8.87	0.64	3.61	0.33	1.85	0.62	3.46	0.45	2.53	0.42	2.35	0.31	1.72	0.95	5.33	0.124	0.70	1.08	6.06
Oatmeal	14.76	0.99	6.71	0.31	2.10	0.63	4.27	1.14	7.72	0.62	4.20	0.25	1.69	0.78	5.28	0.48	3.25	0.23	1.56	0.86	5.83

Table II. Amino Acid Content of Farm Feeds (*Continued*)

Product	Crude Protein, G. per 100 G. Product	Arginine, % Sample	Arginine, % Crude protein	Histidine, % Sample	Histidine, % Crude protein	Isoleucine, % Sample	Isoleucine, % Crude protein	Leucine, % Sample	Leucine, % Crude protein	Lysine, % Sample	Lysine, % Crude protein	Methionine, % Sample	Methionine, % Crude protein	Phenylalanine, % Sample	Phenylalanine, % Crude protein	Threonine, % Sample	Threonine, % Crude protein	Tryptophan, % Sample	Tryptophan, % Crude protein	Valine, % Sample	Valine, % Crude protein
Rice by-products																					
Rice bran	12.54	1.07	8.53	0.35	2.79	0.55	4.38	0.89	7.10	0.67	5.34	0.24	1.91	0.58	4.62	0.49	3.91	0.24	1.91	0.75	5.98
Rice, polish	12.78	1.04	8.14	0.32	2.50	0.44	3.44	0.81	6.34	0.64	5.01	0.21	1.64	0.48	3.76	0.45	3.52	0.19	1.49	0.75	5.87
Wheat by-products																					
Wheat bran	14.58	1.09	7.48	0.44	3.02	0.54	3.70	0.92	6.31	0.64	4.39	0.24	1.65	0.55	3.77	0.52	3.57	0.41	2.81	0.81	5.56
Wheat germ meal	28.08	2.08	7.41	0.64	2.28	0.97	3.45	1.67	5.95	1.84	6.55	0.46	1.64	1.11	3.96	1.11	3.95	0.30	1.07	1.41	5.02
Wheat grey shorts	15.88	0.96	6.04	0.36	2.27	0.58	3.65	0.93	5.86	0.66	4.16	0.24	1.51	0.57	3.59	0.49	3.08	0.30	1.89	0.78	4.91
Wheat, Red Dog	14.22	0.55	3.87	0.29	2.04	0.59	4.15	1.02	7.17	0.31	2.18	0.22	1.55	0.66	4.64	0.40	2.81	0.22	1.55	0.63	4.43
Wheat shorts	16.85	1.07	6.35	0.48	2.85	0.63	3.74	1.03	6.11	0.68	4.04	0.30	1.78	0.65	3.86	0.59	3.50	0.27	1.60	0.87	5.16
Oil Seed Residues																					
Babassu meal	22.72	3.19	14.04	0.41	1.81	0.88	3.87	1.40	6.17	0.98	4.31	0.53	2.33	1.35	5.94	0.71	3.13	0.24	1.06	1.19	5.24
Castor flour	65.03	8.39	12.90	1.36	2.09	3.46	5.32	4.16	6.40	2.20	3.38	1.16	1.78	3.38	5.19	2.50	3.84	0.93	1.43	4.38	6.74
Castor pomace	39.79	3.99	10.03	0.67	1.68	1.85	4.65	2.25	5.65	0.12	3.02	0.58	1.46	1.86	4.68	1.29	3.24	0.44	1.11	2.15	5.40
Copra meal	22.22	2.54	11.43	0.38	1.71	0.89	4.00	1.40	6.30	0.68	3.06	0.35	1.59	0.94	4.23	0.84	3.78	0.21	0.94	1.22	5.49
Cottonseed meal	39.61	4.38	11.02	1.07	2.70	1.59	4.01	2.46	6.20	1.67	4.20	0.59	1.49	2.09	5.25	1.38	3.47	0.63	1.59	1.98	4.98
Cottonseed flour (Proflo)	54.07	6.11	11.30	1.39	2.57	2.13	3.94	3.37	6.23	2.25	4.16	0.87	1.61	2.81	5.20	1.82	3.36	0.84	1.55	2.62	4.84
Linseed meal	36.73	3.41	9.28	0.66	1.80	1.68	4.57	2.19	5.96	1.33	3.62	0.61	1.66	1.65	4.49	1.39	3.78	0.64	1.74	2.04	5.55
Palm kernel meal	19.16	2.54	13.26	0.31	1.62	0.76	3.97	1.23	6.42	0.66	3.44	0.41	2.14	0.82	4.28	0.60	3.13	0.20	1.04	1.03	5.38
Peanut meal	38.95	4.02	10.33	0.84	2.16	1.69	4.33	2.60	6.68	1.38	3.53	0.41	1.04	1.94	4.97	1.16	2.98	0.47	1.22	1.88	4.82
Peanut flour	61.00	6.87	11.26	1.32	2.16	2.64	4.33	4.11	6.74	1.95	3.20	0.62	1.02	3.10	5.08	1.63	2.67	0.78	1.28	2.83	4.64
Safflower meal	22.10	1.72	7.78	0.44	1.99	0.85	3.85	1.22	5.52	0.60	2.71	0.34	1.54	1.16	5.25	0.65	2.94	0.26	1.18	1.09	4.93
Sesamine meal	46.08	5.49	11.91	1.02	2.21	1.97	4.27	3.19	6.92	1.27	2.76	1.22	2.65	2.18	4.73	1.68	3.64	0.88	1.91	2.33	5.06
Soybean meal	45.29	3.38	7.46	1.12	2.49	2.49	5.50	3.48	7.69	2.79	6.17	0.63	1.39	2.20	4.86	1.82	4.03	0.76	1.69	2.45	5.40
Soybean protein (commercial)	79.50	5.72	7.20	1.85	2.33	4.65	5.85	6.18	7.77	4.59	5.77	0.93	1.17	4.40	5.53	2.83	3.56	1.16	1.46	4.09	5.14
Sunflower seed meal	21.02	1.63	7.76	0.46	2.19	0.95	4.52	1.25	5.95	0.80	3.81	0.46	2.19	1.76	5.12	0.72	3.43	0.29	1.38	1.03	4.90
Tung meal	20.88	2.27	10.87	0.48	2.30	1.03	4.93	1.58	7.57	0.87	4.17	0.47	2.24	1.52	7.28	0.96	4.60	0.35	1.68	1.74	8.33
Walnut oil meal	13.03	0.97	7.44	0.21	1.61	0.42	3.22	0.68	5.22	0.28	2.15	0.16	1.23	0.43	3.30	0.34	2.61	0.20	1.53	0.50	3.82
Peas and Beans																					
Black-eye peas	22.31	1.43	6.41	0.63	2.82	1.03	4.62	1.61	7.22	1.47	6.59	0.34	1.52	1.20	5.38	0.80	3.58	0.23	1.03	1.18	5.29
Cow peas, mixed	24.14	1.27	5.27	0.73	3.03	1.14	4.72	1.73	7.17	1.52	6.30	0.28	1.16	1.25	5.18	1.04	4.31	0.32	1.33	1.34	5.56
Mexican Pinto beans	22.58	1.55	6.85	0.64	2.83	1.14	5.05	1.11	4.92	1.60	7.08	0.26	1.15	1.20	5.31	1.09	4.82	0.32	1.42	1.23	5.54
Soybeans, Laredo	35.02	2.40	6.84	0.80	2.29	1.88	4.68	2.03	5.80	2.26	6.47	0.48	1.37	1.67	4.77	1.29	3.68	0.56	1.60	1.89	5.39
Soybeans, Arksay	39.77	2.95	7.42	0.90	2.26	2.13	5.36	3.05	7.68	2.68	6.73	0.62	1.57	2.07	5.20	1.57	3.96	0.56	1.42	2.06	5.18
Soybeans, Red Tanner	42.08	3.27	7.78	1.00	2.39	2.21	5.26	3.24	7.71	2.64	6.28	0.54	1.28	2.14	5.08	1.57	3.73	0.56	1.33	2.30	5.46
Miscellaneous																					
Alfalfa leaf meal	19.47	0.96	4.93	0.42	2.18	1.00	5.14	1.54	7.91	1.08	5.55	0.30	1.54	0.99	5.08	0.90	4.62	0.41	2.11	1.10	5.65
Animal protein factor[a]	52.94	1.98	3.74	0.49	0.93	1.58	2.98	1.79	3.38	1.63	3.08	0.40	0.76	1.04	1.96	1.49	2.81	0.31	0.59	1.67	3.15
Antibiotic feed supplement[b]	46.13	1.27	2.75	0.98	2.12	1.98	4.29	1.80	3.90	2.08	4.51	0.45	0.98	1.67	3.62	0.95	2.06	0.40	0.87	1.20	2.60
Citrous pulp	5.82	0.28	4.81	0.09	1.55	0.18	3.10	0.31	5.33	0.20	3.44	0.08	1.37	0.18	3.09	0.18	3.09	0.06	1.03	0.25	4.30
Coffee pulp	10.59	0.38	3.68	0.21	1.98	0.40	3.78	0.58	5.48	0.36	3.40	0.28	2.64	0.33	3.12	0.33	3.12	0.10	0.94	0.50	4.72
Cow pea foliage, dry	26.01	1.11	4.27	0.45	1.73	1.26	4.84	2.00	7.69	1.08	4.15	0.51	1.96	1.25	4.81	1.06	4.08	0.52	2.00	1.43	5.50
Gourd seed meal *C. foetidissima*	63.50	9.05	14.25	1.18	1.86	2.78	4.38	4.22	6.65	2.07	3.26	1.23	1.94	2.91	4.58	1.65	2.60	1.02	1.61	3.05	4.80
Pumpkin seed	30.81	3.39	11.00	0.65	2.10	1.12	3.64	1.65	5.37	1.56	5.06	0.63	2.06	1.32	4.28	0.72	2.34	0.46	1.49	1.30	4.21
Sweet potato stock feed	3.88	0.094	2.42	0.061	1.57	0.20	5.15	0.27	6.96	0.076	1.96	0.08	2.06	0.20	5.15	0.18	4.64	0.069	1.78	0.25	6.44

[a] Dried fermentation product prepared as source of vitamin B_{12}. Amino acid composition of products is due to the carrier substance. Other animal protein factor preparations may be quite different in amino acid content according to the process used.
[b] Dried fermentation by-product from bacitracin production.

low lysine, methionine, and tryptophan content of the protein in bone meal confirms the generally accepted conclusion that the protein in this product is of low nutritional value.

Fermentation Feeds. Different samples of the same product will vary somewhat in amino acid composition in such products as distiller's dried grains, where the proportion of different grains used in the fermentation varies according to the art and practice of the distiller. The composite samples prepared by the Distiller's Feed Research Council probably represent as nearly average samples as could be obtained. A number of products included in the fermentation feeds are deficient in lysine, as are the grains from which they were made. The high lysine content of yeast is of interest. Some good sources of methionine are to be found among the fermentation feeds. As judged by the value of 1.00% of the protein as the tryptophan requirement of the chick, and 0.75% of the protein as the requirement for the pig, two thirds or more of the samples of fermentation feeds were moderately deficient in tryptophan for the chick but all except one were adequate for the pig.

Fish By-products. As a group, the fish by-products are good sources of lysine. The samples of herring meal, perch meal, sardine meal, and white fish meal were all particularly high in both lysine and methionine.

Grains. The lysine deficiency of the common grains is well known. None of the grains which are generally available in quantities for animal feeds had sufficient lysine to meet the needs of either chicks or pigs. The average value for the lysine content of the different strains of oats indicates only a very moderate deficiency, while the deficiency of wheat and the grain sorghums as a group is very marked. The relatively high lysine content of buckwheat is of interest.

Among the samples of readily available grains, yellow corn and hog millet had the highest percentage of methionine in the protein. These two grains, and only these two, contained adequate levels of methionine for the chick according to the criteria used in this discussion.

The data reported in Table II do not indicate a tryptophan deficiency in any of the grains for either chicks or pigs.

Grain By-products from Milling and Processing. When different anatomical parts of a seed or grain are separated during processing, it is to be expected that the products will vary in amino acid distribution. In practice, such separations are far from complete and in a sense, they are more or less arbitrary. Variations in the amino acid content of different samples of miller's by-products are therefore to be expected.

With respect to lysine content, the data show that the germ proteins of corn, wheat, and grain sorghums are higher in lysine than the whole seeds from which they were obtained. In contrast, corn gluten and grain sorghum gluten are products of low lysine content. Corn gluten is an outstanding source of methionine, but it is low in tryptophan as well as lysine.

Oilseed Residues. The unique position of soybean oil meal with its relatively high content of lysine (6.17% of the protein) is of particular interest. It is generally recognized that the limiting amino acid in a typical corn-soybean meal ration is methionine. When other oilseed meals are substituted for soybean meal, the amino acid which is the limiting factor for rapid growth is more likely to be lysine.

Kuiken and Lyman (*8*) and Lyman, Chang, and Couch (*12*) have shown that only part of the lysine in some samples of cottonseed meal is available. Chemical methods for evaluating protein quality in cottonseed meal have been reported (*4, 12*).

The oilseed meals contain some good sources of methionine; these include babassu meal, palm kernel meal, sesame meal, sunflower seed meal, and tung meal. Tung meal cannot be used because of its toxic qualities. The oilseed meals are, without exception, good sources of tryptophan.

In a study of the amino acid composition of cottonseed, soybean, and peanut products, Lyman, Kuiken, and Hale (*14*) found excellent agreement in the amino acid content of samples of the same product obtained from different parts of the country. Likewise, Kuiken and Lyman (*7*) found only small differences in the amino acid distribution in 20 strains of soybeans.

Peas and Beans. The limited number of peas and beans analyzed would indicate that the relatively high lysine content of soybeans is characteristic of other members of the group as well. Peas and beans are good sources of tryptophan.

Summary

One hundred and fifteen samples of farm feeds and materials with potential value as farm feeds were analyzed for each of the 10 essential amino acids by microbiological assay. The materials analyzed include the algae, animal by-products, fermentation feeds, fish by-products, grains, grain by-products from milling and processing, oilseed meals and residues, peas, beans, and alfalfa meal.

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