Amino Acid Composition of Seed Meals from Forty-One Species of Cruciferae

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Seed meals of 41 species from 29 genera of Cruciferae were analyzed for 18 amino acids. Crude protein content ranged from 14 to 61%; lysine, from 167 to 466 mg. per gram of nitrogen; and methionine, from 62 to 120 mg. Eight seed meals with 34 to 47% crude protein contained high lysine (above 341 mg.) and high methionine (above 95 mg.). Hydroxyproline occurred in all meals examined. By Mitchell's chemical method of evaluating nutritive quality, 31 meals rated scores of 70 or more. By the FAO method, only 17 scored over 70.

Domestically produced vegetable oils contain glycerides composed predominantly of 18-carbon fatty acids. In contrast, many cruciferous seeds contain oils high in erucic acid, a 22-carbon monoene (*7*, *8*). Such oils or their derived products might have industrial utilization noncompetitive with currently used oils (*20*). The value of the extracted seed meal depends on its nutritional quality (*3*, *16*), which is most easily indicated by its amino acid composition. Ion exchange chromatography facilitates quantitative analysis for each amino acid needed in this nutritional evaluation. The literature contains few data on the amino acids in cruciferous seeds (*14*). Therefore, 41 species from 29 genera were analyzed for their amino acids as part of a chemical screening program concerned with plants uncultivated or little cultivated in the U. S. Species of an additional genus, *Lesquerella*, are also being examined and will be reported separately.

There are over 2500 species from 350 genera in the family Cruciferae. The plants are mostly herbaceous and widely adapted, primarily in cool and temperate zones, including arid regions (*5*). Two cruciferous plants, rape and mustard, are well established, cultivated crops in India, Pakistan, and Canada, but neither is grown for its oil in the U. S. (*2*). Many other members of Cruciferae are used as vegetables, for condiments, and as ornamentals. Consequently, cruciferous plants with crop potential for the United States may well be found.

Materials and Methods

Preparation of Samples. Each seed meal consisted of kernel and seed coat. Two meals, from *Dithyrea wislizenii* and *Isatis tinctoria*, also contained pericarp. Methods of grinding, extracting, and acid hydrolyzing the samples have been described earlier (*18*). Hydrolyzates were stored at 4° C. and analyzed within 1 week after preparation.

Methods of Analysis. Nitrogen contents of the solvent-extracted meals, soluble hydrolyzates, and insoluble humins were determined by the Kjeldahl method. Seventeen amino acids were determined with the Spinco Model MS amino-acid analyzer by the method of Spackman, Stein, and Moore (*15*). Hydroxyproline was separated from aspartic acid by operating the 150-cm. column at 30° and 50° C. Because of its extensive destruction during acid hydrolysis, cystine was determined after oxidation to cysteic acid by the method of Schram, Moore, and Bigwood (*13*). Tryptophan was not determined because there was no suitable method for the type of material analyzed.

Phenylalanine, threonine, and serine values obtained from a sample of *Brassica juncea* meal hydrolyzed for 96 hours showed respective losses of 7, 16, and 40%, when compared with values from the usual 24-hour hydrolysis. Respective losses of the same amino acids for a 96-hour hydrolysis of *Crambe abyssinica* meal were 11, 13, and 37%. If the rate of destruction during the first 24 hours of hydrolysis were similar to the rate between 24 and 96 hours, serine, showing the greatest loss at 96 hours, would be about 13% destroyed at 24 hours. No corrections were applied to 24-hour hydrolyzates.

Fourteen analyses of standard solutions containing 19 amino acids and ammonia were determined with the analyzer. The relative standard deviations $\left(\frac{S.D.}{\bar{x}} \times 100\right)$ for the amino acids ranged from 1.7 to 7.3%. Eleven amino acids had relative standard deviations between 3 and 5%. Amino acids eluting from the column near each other—such as glycine and alanine, and tyrosine and phenylalanine—had the highest relative standard deviations.

Methods of Calculation. Amino acid nitrogen (Table I) is the sum of nitrogen from each known amino acid measured colorimetrically as eluted from the ion exchange columns. Ammonia nitrogen was similarly determined. Unknown nitrogen was calculated by difference.

The results for amino acids are expressed on the basis of 1 gram of nitrogen as recommended by the Food and Agricultural Organization of the United Nations. (FAO) (*4*) (Table II).

Results and Discussion

Crude Protein. In comparison with cereal grains, seeds from Cruciferae are high in protein. Seeds from 15 species contained between 30 and 35%

crude protein and those from 24 contained 20 to 30%. Solvent-extracted meals from 13 species contained 44 and 61% crude protein (Table I) and in this respect compared favorably with commercial, solvent-extracted soybean meal.

In 35 seed meals (Table I), 70.2 to 81.9% of the total nitrogen was accounted for as the common amino acids, and no meal had less than 63.2%. This percentage of total nitrogen may be a more useful measure of the protein content of a meal than the total nitrogen because it is that part of the total nitrogen accounted for as the common amino acids.

Unidentified Nitrogenous Substances. The nitrogen of the insoluble material (humin) from acid hydrolysis is of unknown origin, but may come from amino acids and other nitrogenous compounds modified or reacted with other seed constituents during hydrolysis. In 24 samples, less than 3% of the total nitrogen appeared in the humin. The crude protein contents of these meals ranged from 35 to 61%. In only six samples did more than 5% of the total nitrogen appear in the humin. Their crude protein contents ranged from 14 to 37% (Table I).

Minor ninhydrin-reactive peaks recorded by the instrument accounted for some of the unknown soluble nitrogen. Sixteen unidentified peaks (levulinic acid and related compounds excluded), four absorbing at 440 mμ, and 12 at 570 mμ, appeared in the analyses of 41 cruciferous meals. They eluted in positions ranging from 32 minutes before hydroxyproline ($R_{hydroxyproline}$ = 0.853) to 30 minutes after ammonia (R_{lysine} = 1.75). The largest unidentified peak from any sample occurred in the analysis of the meal from *Lunaria annua*. It eluted at the pH 4.25 breakthrough, 38 minutes prior to methionine ($R_{methionine}$ = 0.954) and, calculated as leucine, represented 0.8% of the nitrogen. The next largest unidentified peak calculated in the same way occurred 45 minutes before lysine (R_{lysine} = 0.648) in the analysis of the meal from *Dithyrea wislizenii* and represented 0.2% of the nitrogen. This same peak, of smaller size, was eluted from all samples and might represent decomposition product(s) of one or more amino acids. Remaining peaks were present in some samples and not in others. The number of unknown peaks eluted from any one sample varied from one to seven. No attempt was made to identify the substances causing these small peaks. Also contributing to the unknown, soluble nitrogen may be degradation products of isothiocyanates and related compounds derived from glucosides present in Cruciferae (*19*). They may or may not react with ninhydrin.

Amino Acids. The average and range for each amino acid in the cruciferous meals show limited variability (Table II). The amino acids with the greatest relative standard deviation are hydroxyproline, cystine, proline, and lysine.

Hydroxyproline has recently been shown to occur frequently in seed meals, but is derived from seed coat or pericarp rather than kernal (*12*, *17*). All seed meals from the Cruciferae (Table II) included seed coat and contained hydroxyproline.

Seed meals from 23 of 41 species contained 90 to 120 mg. of methionine and 90 to 202 mg. of cystine per gram of nitrogen (Table II). Comparison with recently reported values for methionine and cystine content of soybeans, 80 to 98 and 87 to 100, respectively (*12*, *14*), shows that cruciferous seeds are as high or higher in their sulfur-containing amino acids.

Seed meals from 12 of 41 species contained 341 to 466 mg. of lysine per gram of nitrogen (Table II), as compared with soybean meal, 410 to 429 (*12*, *14*). Eight species high in lysine (341 to 466) were also high in methionine (95 to 120) and had crude protein contents ranging from 34 to 47%. These eight species, *Brassica besseriana*, *B. campestris*, *B. hirta*, *B. napus*, *B. rapa*, *Capsella bursa-pastoris*, *Eruca sativa*, and *Lepidium lasiocarpum*, merit further evaluation as sources of supplemental protein in feeds and foods.

The t test was used at the 99% level to compare the amino acid content of

Table I. Protein and Oil Content of Cruciferae Seed Meals and Nitrogen Distribution after Acid Hydrolysis

Genera and Species	Oil,[b] %	Protein, %[a] Whole seed[b]	Protein, %[a] Extracted meal[b]	Nitrogen Distribution as % of Total Nitrogen: Amino acids	Ammonia	Insoluble	Unknown[c]
Alyssum saxatile	18.3	26.9	32.9	69.2	12.7	3.5	14.6
Arabis alpina	30.6	24.4	35.1	71.5	11.6	8.5	8.4
Brassica besseriana	39.3	26.2	43.2	77.2	13.4	2.7	6.7
Brassica campestris[d]	42.7	23.8	41.5	74.6	12.8	2.9	9.7
Brassica carinata	29.7	32.6	46.4	71.5	12.3	4.0	12.2
Brassica hirta	28.1	31.2	43.4	71.5	14.3	2.3	11.9
Brassica juncea[e]	37.2	27.5	43.8	73.1	12.5	3.5	10.9
Brassica napus[f]	44.7	23.8	43.1	71.9	12.4	2.4	13.3
Brassica nigra[e]	32.4	31.2	46.2	74.7	13.2	2.7	9.4
Brassica oleracea var. *capitata*	25.9	33.8	45.6	73.3	11.3	2.3	13.1
Brassica rapa	30.7	26.2	37.8	71.9	12.9	3.8	11.4
Cakile edentula	48.7	31.2	60.8	70.2	15.3	1.7	12.8
Camelina microcarpa	34.1	25.6	38.8	75.7	11.6	3.1	9.6
Camelina sativa	33.2	33.1	49.6	74.5	11.9	2.2	11.4
Capsella bursa-pastoris	25.9	32.5	43.8	74.8	12.6	1.8	10.8
Cheiranthus cheiri	29.5	27.5	39.0	71.6	12.0	2.7	13.7
Conringia orientalis	27.3	30.6	42.1	75.4	12.6	4.7	7.3
Crambe abyssinica	35.5	31.5	48.8	72.2	12.7	2.3	12.8
Descurainia pinnata var. *ochroleuca*	35.9	26.9	42.0	74.0	12.0	1.9	12.1
Descurainia sophia[g]	37.5	27.5	44.0	75.2	12.5	2.4	9.9
Dithyrea wislizenii	3.9	16.9	17.6	63.2	13.8	11.6	11.3
Eruca sativa	34.6	30.6	46.8	80.0	16.5	1.5	2.0
Erysimum perofskianum	35.5	28.0	43.3	74.8	12.4	3.1	9.7
Hesperis matronalis	31.8	24.9	36.5	72.0	10.7	2.7	14.6
Iberis amara	26.8	28.1	38.4	74.5	10.9	2.5	12.1
Iberis umbellata	25.6	34.4	46.2	81.9	12.1	1.9	4.1
Isatis tinctoria	12.6	12.5	14.3	69.8	12.3	9.1	8.8
Lepidium lasiocarpum	23.5	26.3	34.4	80.8	13.2	3.1	2.9
Lepidium sativum	21.9	31.2	40.0	70.8	12.5	2.8	13.9
Lepidium virginicum	19.7	26.2	32.4	74.0	12.4	6.3	7.3
Lobularia maritima	35.6	26.2	40.7	72.8	11.4	2.4	13.4
Lunaria annua	32.9	24.6	36.7	68.8	9.4	6.1	15.7
Malcolmia maritima	20.4	23.8	29.9	69.0	12.2	3.5	15.3
Matthiola bicornis[h]	29.4	35.3	50.0	74.6	13.1	3.4	8.9
Nasturtium officinale	27.6	29.4	40.6	72.8	12.1	2.9	12.2
Nerisyrenia camporum	37.6	27.5	44.1	74.3	14.5	2.2	9.0
Raphanus sativus	41.7	30.6	52.5	73.3	12.7	4.3	9.7
Selenia grandis	18.5	21.2	26.0	65.0	12.4	5.5	17.1
Sisymbrium sp.	36.2	31.2	48.9	76.0	11.4	2.5	10.1
Stanleyella texana	35.6	27.5	42.7	73.7	12.4	2.3	11.6
Thlaspi arvense	32.0	23.8	35.0	71.8	11.2	2.9	14.1

[a] % N × 6.25.
[b] On dry basis.
[c] By difference.
[d] Average, four samples, one from Maryland, one from Sweden, and two from Canada.
[e] Average, two accessions.
[f] Average, four samples, two from Sweden and two from Canada.
[g] Average, two accessions, one run in duplicate.
[h] Average, duplicate determinations.

Table II. Amino Acid Composition and Protein Score of Cruciferae Seed Meals

(Milligrams of amino acid per gram of nitrogen[a])

Genera and species	Lysine	Methionine	Cystine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Histidine	Arginine	Glycine	Alanine	Aspartic acid	Glutamic acid	Hydroxyproline	Proline	Serine	MEAAi-CS[b]	PS[c]
Alyssum saxatile	299	81	99[d]	224	371	220	169	238	292	138	363	317	236	528	828	61	319	239	69–39[e]	59[e]
Arabis alpina	332	71	124	207	369	278[f]	164	231	267	150	421	326	260	436	868	64	297	235	70–33	50
Brassica besseriana	348	99	160	240	404	246	179	261	300	172	438	299	256	409	1120	88	390	239	76–48	73
Brassica campestris[g]	378	120	152	237	404	236	171	249	307	170	370	286	251	411	1048	62	416	239	75–55[h]	86
Brassica carinata	296	91	139	212	370	212	151	224	270	152	437	258	223	407	1071	35	349	226	69–45	68
Brassica hirta	362	97	124	207	412	233	206	171	300	164	337	306	246	466	1006	62	355	234	71–48[i]	73
Brassica juncea[j]	335	104	159	236	395	240	167	251	296	161	401	305	258	404	989	54	340	234	74–52	82
Brassica napus[g]	364	111	152	228	395	221	164	240	301	161	351	268	241	386	1038	66	399	234	74–52[h]	82
Brassica nigra[j]	274	94	148	235	391	234	165	232	288	158	472	295	239	403	1076	69	381	215	71–45	68
Brassica oleracea var. *capitata*	294	98	144	213	372	220	218	242	278	144	407	300	227	442	1097	75	417	226	71–48	73
Brassica rapa	390	109	119	224	364	217	166	274	292	149	356	271	253	520	936	69	304	243	74–52[i]	77
Cakile edentula	167	97	160	205	342	226	140	184	261	146	550	273	199	375	1188	16	303	235	62–39[k]	73
Camelina microcarpa	300	93	112	216	343	221	165	248	286	128	482	326	255	516	998	80	292	277	68–45	68
Camelina sativa	262	112	155	230	387	245	165	228	313	139	478	291	243	501	1046	24	318	244	71–54[h]	82
Capsella bursa-pastoris	341	102	104	226	365	227	179	240	302	139	487	312	250	514	906	45	294	236	71–48	73
Cheiranthus cheiri	307	75	127	224	387	252	194	249	304	134	407	316	251	490	828	72	327	216	71–36	55
Conringia orientalis	301	82	131	205	391	225	202	217	293	159	477	314	266	433	888	99	394	244	70–39	59
Crambe abyssinica	314	106	177	239	382	246	172	255	287	157	379	296	238	421	992	39	385	227	74–52	77
Descurainia pinata var. *ochroleuca*	281	91	110	216	350	237	180	249	287	142	473	368	247	481	912	94	294	254	70–45	68
Descurainia sophia[l]	298	91	102	233	357	232	193	232	299	152	451	393	244	490	950	108	304	236	71–42	64
Dithyrea wislizenii	318	62	75	187	294	187	131	193	262	99	271	214	218	475	733	95	707	209	58–30	45
Eruca sativa	450	98	163	220	392	236	207	232	324	169	409	309	274	459	1044	109	384	253	76–48	73
Erysimum perofskianum	309	84	107	225	375	252	217	253	310	139	463	365	244	528	858	72	320	232	70–42	64
Hesperis matronalis	348	83	116	207	377	237	198	237	290	142	401	343	241	450	824	121	333	240	70–39	59
Iberis amara	383	76	124	211	352	233	174	228	282	164	503	281	252	403	800	107	374	198	70–36	55
Iberis umbellata	310	81	140	212	365	221	147	231	264	157	546	284	250	429	924	51	389	201	69–39	59
Isatis tinctoria	327	102	148	211	370	233	137	212	283	139	377	315	232	421	872	148	346	225	69–48	73
Lepidium lasiocarpum	466	102	142	244	355	262	195	229	282	145	462	411	259	472	1026	90	336	294	75–48	73
Lepidium sativum	292	103	87	266	412	281	183	217	324	137	407	294	252	499	858	49	280	221	72–48	71[m]
Lepidium virginicum	321	90	162	231	345	272	166	227	279	143	426	351	244	416	985	48	357	264	71–42	64
Lobularia maritima	315	94	130	227	341	219	160	252	285	155	411	344	269	448	860	52	336	279	71–45	68
Lunaria annua	325	78	202	230	360	229	232	262	276	142	351	346	228	469	661	141	286	258	73–36	55
Malcolmia maritima	359	81	131	222	374	253	198	253	287	140	398	276	256	428	713	34	293	214	73–39	59
Matthiola bicornis[n]	183	91	151	211	372	245	185	193	265	135	544	414	225	420	1034	51	327	204	65–42[k]	68
Nasturtium officinale	341	82	137	235	390	241	172	217	298	141	446	261	251	438	959	80	350	213	72–39	59
Nerisyrenia camporum	260	86	141	211	353	206	168	258	255	154	465	362	251	499	988	81	267	306	68–42	64
Raphanus sativus	300	109	180	220	387	228	170	235	293	171	439	258	242	408	1001	70	416	216	72–51[h]	82
Selenia grandis	338	87	147	201	333	190	167	241	267	118	351	247	227	399	772	143	331	213	67–42	64
Sisymbrium sp.	286	87	96	235	365	246	209	233	298	155	468	382	236	504	979	108	328	247	70–42	64
Stanleyella texana	306	99	88	231	392	236	180	239	287	145	366	382	276	530	978	82	320	259	70–48	71[m]
Thlaspi arvense	300	75	111	225	397	250	179	259	304	138	395	338	263	467	906	59	322	226	71–36	55
Minimum value	167	62	75	187	294	187	131	171	255	99	271	214	199	375	661	16	267	198		
Maximum value	466	120	202	266	412	281	232	274	324	172	550	414	276	530	1188	148	707	306		
Average value	319	92	134	222	372	235	178	235	289	147	425	315	246	454	940	75	348	237		
Standard deviation	54	12	27	14	24	20	22	22	16	14	61	46	15	44	115	31	70	24		
Relative standard deviation, %	17	14	20	6	6	8	13	9	6	10	14	14	6	10	12	42	20	10		

[a] To convert to grams per 16 grams of nitrogen multiply by 0.016.

[b] Modified essential amino acid index (MEAAi). Chemical score (CS) of the most limiting amino acid (*9*).

[c] Protein score (PS) based on FAO provisional pattern (Table IV) (*4*).

[d] Value outside ± one standard deviation underlined once.

[e] Methionine limiting except where noted.

[f] Value outside ± two standard deviations underlined twice.

[g] Average, four samples (Table III).

[h] Isoleucine limiting.

[i] Methionine and isoleucine limiting.

[j] Average, two accessions.

[k] Lysine limiting.

[l] Average, two accessions, one in duplicate.

[m] Methionine + cystine limiting.

[n] Average, duplicate determinations.

Table III. Amino Acid Composition of Different Varieties of Two Species of Brassica

(Milligrams of amino acid per gram of nitrogen)

Species and variety	Lysine	Methionine	Isoleucine	Leucine	Phenylalanine	Tyrosine	Threonine	Valine	Histidine	Arginine	Glycine	Alanine	Aspartic acid	Glutamic acid	Hydroxyproline	Proline	Serine
B. campestris[a]	366	132	246	421	272	201	264	327	169	364	309	273	423	1066	65	407	257
B. campestris 'Arlo'[b]	351	114	234	400	224	161	237	303	166	369	286	235	407	1083	48	385	230
B. campestris 'Polish'[b]	403	113	225	382	221	159	237	285	177	366	269	228	396	986	56	393	226
B. campestris 'Rapido II'[c]	393	121	242	410	229	164	253	312	168	382	283	266	416	1055	82	478	242
B. campestris average[d]	378	120	237	404	236	171	249	307	170	370	286	251	411	1048	62	416	239
B. napus average[d]	364	111	228	395	221	164	240	301	161	351	268	241	386	1038	66	399	234
B. napus 'Golden'[b]	376	108	229	401	224	157	239	294	166	367	274	249	396	1029	34	419	233
B. napus 'Regina II'[b]	353	106	219	379	206	155	224	294	159	349	256	224	371	1040	62	383	224
B. napus 'Regina II'[c]	361	113	230	396	227	170	243	306	160	354	267	243	389	1028	69	401	238
B. napus 'Matador'[c]	367	116	233	403	229	174	254	312	157	333	275	246	387	1057	96	391	243

[a] Variety unknown. [b] From Canada. [c] From Sweden. [d] Cystine determined on only one variety of each species.

Table IV. Amino Acid Requirements Established for Humans, Pigs, and Chicks

Amino Acid	Milligrams per Gram of Nitrogen		
	Human[a]	Pig[b]	Chick[c]
Lysine	270	254	312
Methionine + cystine[d]	270(144)	234(117)	250(141)
Isoleucine	270	234	188
Leucine	306	234	438
Phenylalanine + tyrosine[d]	360(180)	195(137)	438(219)
Threonine	180	156	188
Tryptophan	90	78	62
Valine	270	156	250
Histidine	...	78	94
Arginine	...	78	375
Glycine	...	...	312

[a] Provisional pattern of FAO (*4*).
[b] Calculated from data given by National Research Council, based on a 16% protein ration (*11*).
[c] Calculated from data given by National Research Council, based on a 20% protein ration (*10*).
[d] Values in parentheses are the minimum required for either methionine or phenylalanine.

all species of *Brassica* seeds reported with that of the remaining cruciferous seeds. Only histidine, methionine, leucine, and glycine were significantly different; all except glycine were higher in the species of *Brassica*.

The amino acid composition of the seed meal of *Dithyrea wislizenii* varied markedly from the average. The t test at the 99% level showed that all amino acids in *D. wislizenii* seeds except lysine, aspartic acid, and hydroxyproline were significantly different from those in the remaining cruciferous seeds.

Varietal Comparison within a Species. Seeds from several varieties of two species of *Brassica* show little difference in amino acid contents (Table III). No significant difference between species for any of the amino acids was shown by the t test at 99% level. Variety Regina II from Sweden and Canada had amino acid compositions similar to each other.

Comparison with Values in the Literature. Partial amino acid content of seeds from 10 of the 41 species (Table II) is reported in the literature (*14, 18, 21*). Values reported in the literature for any one amino acid in a given species vary more than the range of values for the same amino acid in the 41 different species reported here.

Nutritional Evaluation. Two of several available chemical methods were used to evaluate the cruciferous seed meals for nutritional quality by comparing their amino acid contents with those in a standard protein (Table II). Mitchell (*9*) used the amino acid composition of egg protein as a standard. The FAO method (*4*) used a provisional pattern.

If the protein score is assumed to be a close approximation to the biological value, any meal with a score of 70 or more is a satisfactory food for growth and maintenance. A food with a score of 60 or less is unsatisfactory (*4*). Protein scores for soybean and a few cereal grains follow:

	Mitchell's MEAAi	FAO's Protein Score
	(Amino acids in parentheses are most limiting by method used)	
Soybean	81 (methionine)	73 (methionine)
Oatmeal	72 (methionine)	64 (methionine + cystine)
Cornmeal	68 (lysine)	50 (tryptophan)
Whole wheat	66 (methionine and lysine)	55 (methionine)

These scores were calculated from the data of Rackis and coworkers for soybeans (*12*) and of Block and Weiss for cereal grains (*1*).

Foods obtained from plant sources are most often deficient in lysine and methionine. On the basis of the rating method of Mitchell (*9*), the sulfur-containing amino acids were the most limiting in all but six cruciferous seed meals. Four meals were limiting in isoleucine and two were limiting in lysine. Two meals were limiting in both methionine and isoleucine. Thirty-one seed meals had a modified essential amino acid index (MEAAi) of 70 or more. Eight of these were from species of *Brassica* and one of the others from *Eruca sativa*, a closely related species. Only one Cruciferae rated below 60.

Rated by the FAO method, only 17 meals from Cruciferae scored over 70 while 12 scored below 60. By this method, all cruciferous seed meals were limiting in the sulfur-containing amino acids.

Nutritional quality may also be evaluated by comparison with the amino acid requirements established for swine (*11*) and chicks (*10*). These requirements are expressed as milligrams of amino acid per gram of nitrogen based on a 16% protein ration for swine and a 20% protein ration for chicks (Table IV). A direct comparison can be made between Tables II and IV. Although this comparison shows that cruciferous seed meals may be better nutritionally for swine than for chicks, no meal would be adequate as the sole protein source at the calculated levels. A high-protein meal with high lysine when mixed with a grain may produce a feed of high-protein quality. A 16% protein ration for swine could be produced by supplementing three parts of corn with one part of meal from *E. sativa.* By calculation, this ration would be adequate in all amino acids. Similarly, four cruciferous seed meals would be adequate sources for nine of the 10 amino acids needed by growing pigs. Fifteen would be adequate sources for eight of the 11 amino acids needed by growing chicks.

The use of cruciferous seed meals as feeds may be limited until more basic knowledge is obtained concerning unpalatable and toxic substances, such as the isothiocyanates and thio-oxazolidones, known to be present in some (*2, 19*). Recently, a bland meal was obtained from mustard seeds (*6*). Removal of the isothiocyanates left a meal showing no evidence of toxicity when fed to rats.

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