Amino Acid Composition of Rice and Rice By-Products[1]

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ABSTRACT

Data are presented from chromatographic analyses of amino acid contents of seven U.S.-milled rices and such milling by-products as bran, polish, bran-plus-polish, millfeed, and hulls. Values for serine, threonine, valine, and isoleucine were corrected by factors based on earlier work. Cystine and methionine were determined after performic acid oxidation. Composition of each milling fraction was very similar for all varieties and process differences. However, appreciable differences occurred between different milling fractions. Ratios of individual to total essential amino acids (A/E) and of total essential amino acids to total amino acids (E/T) in milling fractions are compared with each other and with values for egg proteins as estimates of nutritional quality. Comparisons of amino acid composition found for milled rice and bran with the rather variable data reported in the current literature show generally higher present values for sulfur amino acids and others requiring special consideration for analysis.

As the protein supply for the ever-increasing world population becomes limiting, the need for accurate data on the essential amino acids of major foods, such as rice, becomes more critical. The development of new foods from rice by-products and the effective use of by-products in feeds call for the most precise data obtainable on desirable and undesirable components.

Essentially all rice bran produced is now used in feeds; it may or may not include the polish or white bran. An increasingly large amount of rice by-product (millfeed) is also being used as feed (1). This product comprises total rice milling by-products and may contain 50 to 65% of rice hulls. The remainder is chiefly bran and polish. The hulls have been shown useful in feed combinations (2,3), and some are ammoniated to increase their feed value (4).

The numerous literature data for amino acid composition of milled rice show wide variation (5,6,7). Microbiological analyses on U.S. brans (8–12) and recent chromatographic analyses on Spanish and Japanese brans (6,13,14) are in considerable conflict. Microbiological analyses on U.S. polishes (8–12) show appreciable differences. Current feed tables (15,16,17) which use amino acid values for bran and polish, apparently based on reported microbiological data, also disagree among themselves. The discrepancy is only partially due to safety factors included in some tables (17).

In the chromatographic analytical procedure, the hydrolysis step is probably the major cause for variability and would be of considerable importance in microbiological procedures. Kohler and Palter (18), in the light of Hill's review on this subject (19), have recently investigated procedural conditions for the chromatographic method that might produce low values for certain amino acids by destruction during acid hydrolysis, by incomplete hydrolysis, or by oxidation. They developed time-of-hydrolysis correction factors based on a number of commodities, and applied average values to feed analyses of wheat products. In this paper we have utilized their procedures and correction factors in analyzing rice products.

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Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

TABLE I. TYPE AND PROTEIN CONTENT OF SAMPLES

Variety		Source	Product	Protein (N X 6.25) % d.b.
1967 Commercial products				
Bluebonnet 50	La.	(Mill A), X-M	Milled rice	8.50
Bluebonnet 50	La.	(Mill A), X-M	Defatted bran	18.50
Bluebonnet 50	Texas	(Mill A)	Parboiled bran	13.75
Belle Patna	Texas	(Mill A)	Bran	15.44
Unspecified	Texas	(Mill A)	Millfeed	6.12
Belle Patna	Texas	(Mill B)	Parboiled bran	9.94
Blue Belle	Texas	(Mill C)	Parboiled bran	17.19
Belle Patna	Texas	(Mill D)	Parboiled bran	14.38
Unspecified	Texas	(Mill E)	Parboiled bran	16.00
Pearl	Calif.	(Mill F)	Bran	10.62
Pearl	Calif.	(Mill F)	Defatted bran	14.94
Pearl	Calif.	(Mill F)	Polish	12.12
Unspecified	Calif.	(Mill F)	Millfeed	6.38
1966 Laboratory-milled samples				
Colusa	Calif		Milled rice	6.44
Colusa	Calif.		Bran-plus-polish	14.50
Caloro	Calif.		Milled rice	7.31
Caloro	Calif.		Bran-plus-polish	15.75
Calrose	Calif.		Milled rice	7.19
Calrose	Calif.		High-protein flour	17.50
Calrose	Calif.		Residual kernels	6.50
Calrose	Calif.		Bran-plus-polish	17.12
Saturn	La.		Milled rice	7.19
Saturn	La.		Bran-plus-polish	17.31
Belle Patna	La.		Milled rice	10.44
Belle Patna	La.		Bran-plus-polish	16.56
Bluebonnet 50	Ark.		Milled rice	8.38
Bluebonnet 50	Ark.		Bran-plus-polish	15.69

MATERIALS AND METHODS

Rice and By-Product Samples

Paddy (rough rice) samples, obtained shortly after the 1966 harvest, were held at about 3°C. until milled. Milled rices (Table I) were prepared from this paddy by use of the McGill sheller and miller according to official government inspection procedures (20); however, any residual paddy, weed seeds, and the like were removed to prevent contamination of the bran. The hull sample was obtained from the milling of Calrose rice as described above.

Bran-plus-polish samples were prepared by combining the bran and polish obtained in milling each of the rices and sieving them through an 18-mesh screen to remove small broken kernels.

Parboiled, regular, and defatted brans, polish, and rice mill by-products (Table I) were freshly milled products supplied by various commercial rice mills.

High-protein flour and residual kernels were prepared by abrasively milling-off surface layers from milled Calrose rice with a CeCoCo rice whitener (21).

All milled rices and milling products were held at about −12°C. until used for analysis.

Procedures

Materials were ground through a 1-mm. screen in a Mikro-Sampl mill (hammer) and thoroughly mixed before sampling.

Samples were hydrolyzed in vacuum at 110°C. for 24 hr. according to

procedure B of Kohler and Palter (18). Amino acid analyses were made by the Spackman, Stein, and Moore protein hydrolysate method (22); the procedure and apparatus of Kohler and Palter (18) were used. For cystine and methionine the performic acid oxidation method of Moore (23) was used according to procedure A of Kohler and Palter (18).

RESULTS AND DISCUSSION

All figures cited are averages from duplicate hydrolyses which were in close agreement. Results are expressed as g. amino acid per 16 g. nitrogen, to be comparable with other values for food or feed analysis (24).

Correction Factors

Several amino acids show significant increases or decreases on prolonged protein hydrolysis at 110°C. and require that correction factors be applied to 24-hr. hydrolysis values. Specifically, serine and threonine are destroyed in moderate degrees. Valine and isoleucine are only released slowly during hydrolysis. Correction factors developed for 24-hr. analysis by Kohler and Palter (18) and used in the present study include those determined for cystine and methionine on the basis of recoveries (Table II). A correction factor of less than 1% for an apparent increase in lysine with time of hydrolysis is too small to be included; this change is apparently caused by conversion of very small amounts of arginine to ornithine, which is not separated from lysine by the systems used. The results reported were reproducible to within 3 to 5%. Nitrogen recoveries off the columns ranged from about 90 to 99% for milled rices and from 84 to 94% for the brans. No adjustments were made on the basis of nitrogen recoveries.

Milled Rices

Despite the 60% variation in nitrogen content of the samples, the data in Table III show that there was relatively minor variation in the amino acid contents of protein in the milled rices examined. The X-M rice, from which bran removal was performed in the presence of a solvent reportedly without removal of any of the aleurone layer from the endosperm, did not differ appreciably in amino acid composition from the other milled rices. A few values differed from the average more than 5%, but none by 10%. Methionine contents showed the greatest coefficient of variability, followed by lysine, tyrosine, histidine, and valine. As protein content increased there were decreases of percentages of histidine ($r = 0.675^*$) and lysine ($r = 0.713^*$) in the protein. The latter confirms an earlier report (25) of this relation in rice. Conversely, there were increases in percentages of methionine ($r = 0.644^*$), valine ($r = 0.420$), and tyrosine ($r = 0.370$) as protein content increased.

TABLE II. AMINO ACID CORRECTION FACTORS

Amino Acid	Correction Factor	Amino Acid	Correction Factor
Cystine[a]	1.091	Serine	1.082
Isoleucine	1.078	Threonine	1.036
Methionine[a]	1.034	Valine	1.081

[a]Determined as cysteic acid and methionine sulfone; correction factor based on recovery experiments.

TABLE III. AMINO ACIDS OF MILLED RICE (g. amino acid per 16.0 g. N)

Amino Acid	Colusa	Caloro	Calrose	Saturn	Belle Patna	Blue-bonnet 50	Blue-bonnet 50 (X-M)	Av. and Std. Dev.
Lysine	3.80	3.39	3.46	3.72	3.28	3.58	3.32	3.51±0.20
Histidine	2.45	2.23	2.22	2.30	2.14	2.31	2.12	2.25±0.11
Ammonia	2.76	2.77	3.11	2.76	3.42	2.72	2.72	2.89±0.27
Arginine	8.50	8.10	8.42	8.67	7.82	8.58	7.90	8.28±0.34
Aspartic acid	9.10	9.22	9.15	9.00	8.74	9.29	8.88	9.05±0.19
Threonine	3.48	3.47	3.54	3.55	3.55	3.66	3.44	3.53±0.07
Serine	5.02	5.02	5.44	5.06	5.18	5.28	4.84	5.12±0.20
Glutamic acid	17.04	17.61	18.19	17.32	18.36	18.39	17.27	17.74±0.56
Proline	4.18	4.52	4.56	4.26	4.32	4.64	4.47	4.42±0.17
Glycine	4.53	4.49	4.54	4.65	4.48	4.68	4.39	4.54±0.10
Alanine	5.48	5.39	5.53	5.48	5.54	5.73	5.40	5.51±0.11
Cystine	2.44	2.68	2.48	2.60	2.51	2.53	2.43	2.52±0.09
Valine	5.92	6.54	6.60	6.36	6.52	6.87	6.32	6.45±0.29
Methionine	2.61	2.73	2.67	3.12	3.11	3.09	2.86	2.88±0.22
Isoleucine	4.46	4.64	4.70	4.54	4.67	4.85	4.55	4.63±0.13
Leucine	7.58	8.07	8.21	7.74	8.17	8.50	7.98	8.04±0.31
Tyrosine	4.57	4.53	5.31	4.76	5.00	5.01	4.87	4.86±0.27
Phenylalanine	5.00	5.30	5.36	5.07	5.22	5.40	5.08	5.20±0.16
% N Recovered	94.8	94.7	99.0	96.2	98.2	98.4	90.6	96.0 ±2.94
% N in sample (d.b.)	1.03	1.16	1.17	1.15	1.67	1.34	1.36	1.27

Not only do the outer layers of milled rice kernels contain higher percentages of protein, but the protein also contains higher percentages of albumin and globulin (26). As albumin is reported relatively high in lysine (5), it might be expected that total protein in the outer layer would contain a higher percentage of lysine than does that in the inner portion of the kernel. This was the case for the Calrose fractions from deep milling, as shown in Table IV, where flour corresponding to the outer 3% of the kernel is compared with the original kernel and with the residual kernel after 9% has been removed. Other published evidence (27), also on a single sample (Bluebonnet 50), showed no greater concentration of lysine in the outer-layer proteins. This may be due to differences in analytical methodology, differences between varieties of rice used, or differences in amounts of aleurone included in the outer-layer flour. Methionine showed the opposite trend from lysine and was reduced in the outer-layer flour as compared with that from the original and residual kernels.

Comparison of present data for some of the amino acids most subject to

TABLE IV. AMINO ACIDS OF HIGH-PROTEIN FLOUR AND RESIDUAL KERNELS OF CALROSE MILLED RICE (g. amino acid per 16.0 g. N)

Amino Acid	High-Protein Flour	Original Kernel	Residual Kernel	Amino Acid	High-Protein Flour	Original Kernel	Residual Kernel
Lysine	3.89	3.46	3.37	Glycine	4.79	4.54	4.43
Histidine	2.49	2.22	2.23	Alanine	5.70	5.53	5.37
Ammonia	2.28	3.11	3.32	Cystine	2.26	2.48	2.44
Arginine	7.90	8.42	8.33	Valine	5.96	6.60	6.52
Asp. acid	8.69	9.15	9.04	Methionine	2.23	2.67	2.69
Threonine	3.56	3.54	3.48	Isoleucine	4.09	4.70	4.61
Serine	4.74	5.44	5.16	Leucine	7.18	8.21	8.02
Glut. acid	16.23	18.19	17.84	Tyrosine	4.00	5.31	4.92
Proline	3.89	4.56	4.42	Phenylal.	4.56	5.36	5.14
% N Recovered	90.2	99.0	98.1	% N in sample (d.b.)	2.80	1.17	1.04

analytical errors with assembled recent literature values (5,6,7) shows considerable differences (Table V). Because samples used by various investigators are different, exact comparisons of experimental results are not possible. However, differing hydrolysis procedures are a major source of variation, and may have been the cause of less than optimal values, as discussed below. The ranges of values reported by Chancel (28) for French rices, and by Cagampang et al. (25) for rices in the collection of the International Rice Research Institute, are evidence of the variation among samples that may be obtained by a single procedure in the hands of one investigator. The Cagampang series shown (25) (low-protein group) includes rices with protein content from 6.15 to 8.86%. However, the practice used by the authors of adjusting 80 to 95% recoveries to a constant 95% nitrogen recovery is questionable because of the differing behavior of various amino acids during hydrolysis.

The low results of Bandemer and Evans (29) for a number of the amino acids in U.S. rices may well be due to incomplete hydrolysis; they autoclaved for 6 hr. at 15-lb. pressure in Erlenmeyer flasks. This would also allow oxidative loss of tyrosine.

Laín and Rodríguez (6) hydrolyzed samples by refluxing with 6N HCl at 120°C. under nitrogen for 22 to 24 hr. They corrected by 10.5% for loss of threonine, 5.3% for serine, and 25% for tyrosine. Despite these conditions and a 97% recovery of nitrogen, a number of their values are low. Refluxing under nitrogen may well be inadequate. Moreover, Kohler and Palter (18) found that necessary corrections at 130°C. were considerably greater than at 110°C., and they would also be larger at 120°C.

Normand et al. (27) hydrolyzed in the presence of phenol to reduce humin formation (30) and used performic acid oxidation in determining cystine. Their somewhat low values for cystine and the slowly hydrolyzed valine and isoleucine may result from the lack of necessary correction factors.

The need for performic acid oxidation in determining the sulfur-containing amino acids is illustrated by the low cystine and methionine values of almost all previously reported data. The variations in results emphasize the need for general use of the best available procedures for sample hydrolysis, because the largest differences are attributable to this phase of the analysis. Collaborative studies would be highly desirable.

Bran and Polish

These two products may well be considered together, because polish (white bran) is often included in various amounts with the usual bran as stock feed. A smaller proportion of polish is used separately as food, going chiefly into baby foods.

Variability among bran samples might expectedly be higher than for milled rice, since brans may contain variable amounts of hull or of endosperm in addition to polish. The agreement among samples and types of bran shown in Table VI is rather surprising. With at least four varieties of rice and products from seven mills, there were few variations of more than 10% among data for individual amino acids.

Laboratory-milled combined bran and polish samples from six rice varieties again showed remarkable similarity in composition (Table VII). The greatest coefficients of variability were found in methionine, histidine, glutamic acid, and arginine.

TABLE V. COMPARATIVE AMINO ACID ANALYSES OF MILLED RICE (g. amino acid per 16.0 g. N)

Amino Acids	Present Study	Chancel (28) (1962)	Bandemer and Evans (29) (1963)	FAO[a] (7) (1963)	Lain and Rodríguez (6) (1965)	Cagampang et al. (25) (1966)	Normand et al. (27) (1966)
Labile and slowly released							
Threonine	3.54 (3.44-3.66)	3.22-3.42	2.5	3.82	3.60	3.0-4.4	3.61
Serine	5.17 (4.84-5.44)	4.77-5.10	3.9	4.77	4.61	4.2-7.4	5.18
Tyrosine	4.86 (4.53-5.31)	4.61-5.35	2.4	6.17	5.74	1.8-4.0	5.49
Valine	6.47 (5.92-6.87)	5.48-6.24	4.3	6.12	5.40	3.4-6.3	5.58
Isoleucine	4.64 (4.46-4.85)	3.85-4.28	2.8	4.23	4.25	3.6-5.0	3.92
Basic and sulfur							
Lysine	3.54 (3.28-3.80)	3.24-3.38	3.5	3.53	3.84	2.9-4.8	3.52
Histidine	2.28 (2.12-2.45)	2.08-2.47	2.1	2.82	1.91	2.0-2.8	2.62
Arginine	8.35 (7.82-8.67)	8.02-9.01	9.6	8.15	7.80	6.9-9.0	8.58
Cystine	2.54 (2.43-2.60)	2.10-2.39	1.5	1.97	1.18	0.3-1.4	1.75
Methionine	2.87 (2.61-3.12)	1.16-1.66	2.1	2.37	2.33	0.7-2.5	...

[a]Compilation.

TABLE VI. AMINO ACIDS OF COMMERCIAL RICE BRANS (g. amino acids per 16.0 g. N)

Amino Acid	Bluebonnet 50 (Mill A)	Parboiled				Defatted		Regular		Weighted Av. and Std. Dev.
		Belle Patna (Mill B)	Unspec. (Mill E)	Blue Belle (Mill C)	Unspec. (Mill D)	Pearl (Mill F)	X-M (Mill A)	Pearl (Mill F)	Belle Patna (Mill A)	
Lysine	4.45	5.19	5.00	4.90	4.12	4.92	4.47	5.22	4.78	4.81±0.37
Histidine	2.59	2.97	2.93	2.91	2.50	2.41	2.58	2.81	2.90	2.71±0.21
Ammonia	2.16	1.77	1.65	1.82	1.75	1.87	1.82	2.14	2.18	1.94±0.20
Arginine	8.68	9.60	9.00	8.93	8.14	7.42	7.89	8.09	8.52	8.28±0.66
Aspartic acid	8.75	8.18	8.26	8.48	7.56	9.59	8.52	9.65	8.89	9.09±0.67
Threonine	3.89	3.88	3.79	3.79	3.36	3.90	3.64	3.89	3.80	3.78±0.17
Serine	5.03	4.88	4.82	4.67	4.50	4.66	4.57	4.64	4.64	4.68±0.17
Glutamic acid	14.77	13.33	13.21	12.41	13.51	13.18	13.76	14.01	13.63	13.58±0.65
Proline	4.36	4.52	4.29	4.27	3.85	4.44	4.04	4.35	4.02	4.23±0.22
Glycine	5.49	5.99	5.58	5.44	5.12	5.49	5.43	5.45	5.40	5.47±0.23
Alanine	6.10	6.52	6.24	5.99	5.64	6.38	5.98	6.44	5.89	6.15±0.29
Cystine	2.12	2.17	2.10	2.18	2.32	2.38	2.44	2.36	2.38	2.32±0.13
Valine	6.46	6.34	6.21	6.43	5.64	6.00	5.52	5.94	6.08	6.00±0.33
Methionine	2.45	2.26	2.40	2.44	2.67	2.17	2.20	2.31	2.38	2.32±0.15
Isoleucine	4.32	3.96	4.00	3.92	3.76	4.00	3.76	4.08	3.80	3.94±0.18
Leucine	7.58	7.08	7.08	7.06	6.65	6.90	6.70	7.03	6.67	6.91±0.29
Tyrosine	3.72	2.98	3.12	3.05	3.29	2.90	3.11	3.15	3.17	3.13±0.24
Phenylalanine	4.80	4.50	4.59	4.64	4.25	4.48	4.25	4.56	4.43	4.47±0.18
% N recovered	93.9	93.0	90.3	90.0	84.2	87.6	86.3	92.0	90.3	89.4±3.2
% N in sample (d.b.)	2.20	1.59	2.56	2.75	2.30	2.39	2.96	2.39	2.47	2.45

TABLE VII. AMINO ACIDS OF LABORATORY-MILLED BRAN INCLUDING POLISH
(g. amino acids per 16.0 g. N)

Amino Acid	Colusa	Caloro	Calrose	Saturn	Belle Patna	Bluebonnet 50	Av. and Std. Dev.
Lysine	5.18	4.98	5.11	5.23	4.88	4.96	5.06±0.14
Histidine	2.79	2.69	2.74	3.07	2.95	2.75	2.78±0.15
Ammonia	2.72	1.88	1.82	1.84	1.96	1.85	2.02±0.35
Arginine	8.02	7.74	7.44	8.16	8.39	8.15	7.98±0.34
Aspartic acid	8.87	8.90	9.42	9.28	8.92	8.90	9.05±0.24
Threonine	3.82	3.82	3.90	3.86	3.80	3.74	3.82±0.05
Serine	4.50	4.47	4.48	4.51	4.74	4.46	4.53±0.11
Glutamic acid	12.80	12.82	12.71	13.42	14.17	12.65	13.10±0.60
Proline	4.39	4.18	4.15	4.15	4.09	3.99	4.16±0.13
Glycine	5.42	5.37	5.59	5.88	5.74	5.41	5.57±0.21
Alanine	6.39	6.23	6.40	6.42	6.16	5.91	6.25±0.20
Cystine	2.49	2.37	2.42	2.53	2.36	2.25	2.40±0.10
Valine	5.88	5.80	5.70	5.82	5.94	5.64	5.80±0.11
Methionine	2.12	1.89	1.78	2.15	2.24	2.03	2.04±0.17
Isoleucine	3.81	3.82	3.69	3.74	3.90	3.68	3.77±0.09
Leucine	6.71	6.59	6.36	6.51	6.82	6.40	6.56±0.18
Tyrosine	2.96	2.94	2.76	2.87	3.00	2.89	2.90±0.08
Phenylalanine	4.37	4.32	4.11	4.22	4.33	4.07	4.24±0.12
% N recovered	90.4	87.1	86.6	89.8	90.9	86.7	88.6±2.0
% N sample (d.b.)	2.32	2.52	2.74	2.77	2.65	2.51	2.59

Since rice bran is used primarily as a feedstuff, the present results on essential amino acids for poultry are compared with recent literature values in Table VIII. The bracketed numbers are appreciably different from our results. The Tamura and Kenmochi bran sample (14) apparently contained the polish but had the embryo largely separated; this would affect the results. Embryo is generally a part of commercially prepared brans and was included in all samples reported herein. Loss of tyrosine, probably by oxidation during hydrolysis, is also seen in the Tamura and Kenmochi results. The 24-hr. reflux in 6N HCl used by Lyman et al. (10,11) would result in losses of methionine and would not completely liberate valine and isoleucine. The low amino acid data of Laín and Rodríguez (6) are likely the result of refluxing under nitrogen, as discussed for milled rices.

Reports on amino acids in rice polish (8–12) are all microbiological except that of Laín and Rodriguez (6). Their data, compared with present results in Table IX,

TABLE VIII. COMPARATIVE DATA ON RICE BRANS FOR ESSENTIAL AMINO ACIDS FOR CHICKS (g. amino acid per 16.0 g. N)

Amino Acid	Present Data[a]	Lyman et al. (10,11) (1956, 1958)	Tamura and Kenmochi (14) (1963)	Laín and Rodríguez (16) (1965)	Combs and Nott Compilation (17) (1967)
Lysine	4.81 (4.45-5.22)	[5.34]	[3.83]	[4.11]	4.61
Histidine	2.71 (2.50-2.97)	2.79	[2.21]	[1.34]	2.77
Arginine	8.28 (7.42-9.60)	8.53	[5.86]	[5.83]	8.46
Threonine	3.78 (3.36-3.90)	3.91	[3.25]	[3.10]	3.84
Glycine	5.47 (5.12-5.99)	n.d.	[4.99]	[3.93]	[7.69]
Tryptophan	n.d.	1.91	n.d.	1.34	1.85
Methionine	2.36 (2.17-2.45)	[1.91]	[1.73]	2.55	[1.85]
Cystine	2.27 (2.10-2.44)	n.d.	[1.97]	[1.15]	[0.77]
Valine	6.07 (5.52-6.46)	5.98	[5.22]	[5.34]	6.00
Isoleucine	3.96 (3.76-4.32)	4.38	[3.45]	[4.70]	4.38
Leucine	6.97 (6.65-7.58)	7.10	6.73	[8.72]	6.92
Phenylalanine	4.50 (4.25-4.80)	4.62	4.23	[5.57]	4.61
Tyrosine	3.17 (2.90-3.72)	3.48	[2.04]	[4.73]	[6.15]

[a]Nine samples.

TABLE IX. AMINO ACIDS OF COMMERCIAL RICE BY-PRODUCTS OTHER THAN BRAN (g. amino acids per 16.0 g. N)

Amino Acid	Hulls (Calrose)	Millfeed		Polish		Amino Acid	Hulls (Calrose)	Millfeed		Polish	
		Calif.	Texas	Present (Pearl)	Lain and Rodriguez (6)			Calif.	Texas	Present (Pearl)	Lain and Rodriguez (6)
Lysine	3.82	4.67	4.51	4.66	4.22	Cystine	1.90	2.24	2.25	2.57	1.26
Histidine	1.22	2.35	2.36	2.70	1.50	Valine	5.69	5.89	6.10	5.57	5.40
Ammonia	3.42	2.82	2.78	1.96	1.39	Methionine	1.76	1.91	2.12	2.78	2.52
Arginine	4.30	7.35	7.35	8.19	6.87	Isoleucine	3.66	3.96	3.98	3.80	4.25
Aspartic acid	8.60	9.32	8.96	8.83	8.98	Leucine	6.47	6.85	7.04	6.58	7.86
Threonine	4.20	3.93	3.96	3.52	3.60	Tyrosine	2.16	2.72	2.80	3.39	5.74
Serine	4.65	4.84	4.84	4.50	4.61	Phenylalanine	4.40	4.58	4.60	4.18	6.39
Glutamic acid	10.42	13.09	14.02	14.60	16.38	Tryptophan	.....	.....	.....	.....	1.42
Proline	6.50	4.79	4.92	3.81	5.61	% N recovered	82.9	91.6	92.0	87.9	98.6
Glycine	5.43	4.91	5.54	5.05	4.42	% N in sample (d.b.)	0.32	1.02	0.98	1.94	1.89[a]
Alanine	6.13	6.30	6.15	5.87	5.67						

[a]On basis of crude protein = N X 6.25, recalculated from Lain and Rodriguez (6).

TABLE X. NUTRITIONALLY SIGNIFICANT AMINO ACID RATIOS[a]

Amino Acid	Milled Rice		Outer-Flour Calrose	Bran-Plus-Polish	Comm. Bran	Polish	Millfeed	Hulls	Hen's Egg (Whole)
	Av.	Calrose							
A/E ratio[b]									
Isoleucine	108	108	105	99	101	99	104	104	129
Leucine	188	188	184	173	177	172	181	183	172
Lysine	82	79	100	134	123	122	120	108	125
Total "aromatics"	336	245	219	189	195	197	192	185	195
Phenylalanine	122	123	117	112	115	109	120	124	114
Tyrosine	114	122	102	77	80	88	72	61	81
Total sulfur acids	126	118	115	117	120	126	111	104	107
Cystine	59	57	58	63	60	67	58	54	46
Methionine	67	61	57	54	60	59	53	50	61
Threonine	83	81	91	101	82	92	103	119	99
Tryptophan	30	30	33	34	33	34	34	38	31
Valine	151	151	156	153	154	145	156	161	141
E/T ratio[c]	2.77	2.68	2.61	2.59	2.62	2.59	2.62	2.68	3.22

[a]Tryptophan taken as a minimum of 1.30 g. per 16.0 g. N.

[b]Individual acid, mg. per g. of total essential amino acids.

[c]Essential amino acid, mg. per g. total amino acid N.

present low values for a number of the acids, as was the case with milled rice and bran.

Hulls and Mill By-Product

The amino acid content of hull proteins, apparently not previously determined, is shown in Table IX together with that of rice millfeed. The crude protein of hulls was marked by relatively high values for proline and low ones for histidine, arginine, and glutamic acid. The content of sulfur amino acids was also relatively low. Hydroxyproline appeared to be absent. The recovered percentages of nitrogen were lower than for other milling products.

Amino acid composition of the two millfeeds was remarkably similar, with appreciable differences only in glycine and glutamic acid. The composition values reflected the large percentage of hulls.

Interproduct Comparisons

Comparisons of the ratios of individual to total essential amino acids (A/E ratio) and of essential to total amino acids (E/T ratio), shown in Table X for the various milling fractions, bring out some interesting similarities and differences.

The E/T ratios of milled rice and, surprisingly, of the hulls were somewhat higher than those of other milling fractions. However, the differences were small. The ratios compared rather favorably with that for the reference egg protein and were considerably above the value of 2.02 for the FAO provisional reference protein (31).

All milling fractions had A/E ratios equal to or greater than that of egg protein for leucine, total aromatics, phenylalanine, total sulfur-containing acids, cystine, and valine. Only millfeed and hulls had lower tyrosine ratios, and this acid became limiting for hull proteins. The same trend occurred for methionine. The threonine ratios showed an inverse relation, with the highest value in hulls. Lysine, as is well recognized, was the limiting amino acid in milled rice. In the high-protein Calrose flour where the lysine ratio was higher, isoleucine was equally limiting; it became the limiting acid in bran, polish, and millfeed.

Nonessential acid contents showed various trends. Bran was highest in histidine (not essential for adult humans) and lowest in proline. Glutamic acid decreased markedly from milled rice to bran to hulls, whereas aspartic acid was quite equally distributed.

These variations among the amino acid contents of the different portions of the grain of rice, the milling fractions, are of course reflections of differing protein composition. It is known, for instance, that the bran protein contains much larger proportions of the water-soluble albumins and salt-soluble globulins than does the milled kernel (5,25). Additionally, albumins contain more lysine (5 to 9%) and globulins less lysine (1 to 4%) than the 2.5 to 4% reported for the predominant protein, the alkali-soluble glutelin.

Unfortunately, the reported amino acid values for the various solubility classes of rice proteins suffer from the wide variability that existed among the earlier values for total rice protein. There is a need for further amino-acid analyses of these protein fractions according to the best present practice, in order to provide more accurate information on the distribution and composition of proteins in the rice grain. Such information is necessary for optimum development of new food and feed products from the milling fractions of rice.

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