AMINO ACID COMPOSITION OF VEGETABLES AND FRUITS FROM THE PHILIPPINES

Dahinog, M. Jr.,* E.D. Rafols**, V. Laspinas***, H.K.F. Lau‡ and T.R.C. Boyde‡

ABSTRACT

Vegetables and fruits commonly consumed in the Philippines were analyzed for their amino acid composition. In all, thirty-three samples were pulverized, lyophilised and then were subjected to acid and alkaline hydrolyses. On the amino acid compositional basis, these foodstuffs would provide a balanced source of dietary protein in general, if supplemented by synthetic phenylalanine and methionine. The minimum amounts of proteins from these foodstuffs needed to provide sufficient essential amino acids to maintain nitrogen balance were computed. The quality of proteins was also estimated by their chemical scores. The significance of these results is discussed.

INTRODUCTION

Fruits and vegetables constitute staple foodstuffs in most Asian countries including the Philippines. Although they are thought to be good sources of vitamins, minerals and fibre, their importance in providing a balanced diet of protein is usually overlooked. Ample research effort has however shown that plant materials can also offer proteins of high nutritional value.

Soya beans and other legumes enjoy great success as major protein sources. Leaf protein concentrates from a variety of plants were found to give favorable balance of essential and nonessential amino acids, comparable to animal products (1, 2). Even the potato tuber, which is commonly considered an "energy food", has also been found to contain protein of high biological value (3, 4). Since the amino acid composition and the biological value of a protein are related, we report here the content of eighteen common amino acids found in thirty-three native Philippine fruits and vegetables.

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*Dept. of Biochemistry, Davao Medical School, Davao City, Philippines.

**Dept. of Biochemistry, Cebu Doctors' College of Medicine, Osmena Blvd., Cebu City, Philippines.

***Dept. of Biochemistry, Gullas College of Medicine, Mandaue City, Philippines.

‡Dept. of Biochemistry, University of Hongkong, Sassoon Road, Hongkong.

MATERIALS AND METHODS

Fresh fruits and vegetables flown in from the Philippines were cut into small pieces, ground in pestle and mortar and lyophilized. The freeze-dried samples were further pulverised and strained through an 80-mesh sieve before use.

Total nitrogen content was determined by sulfuric acid hydrolysis in the presence of selenium dioxide (5) and nesslerisation with a modified Nessler reagent according to Middleton (6). Crude protein was estimated by multiplying 6.25 the nitrogen concentration and is reported on an as-is basis (lyophilized samples).

Sample hydrolysis prior to amino acid analysis was carried out at 110^{o}C with 6 M HCl for 24 hours using the heat-sealed, vacuum tube method of Savoy et al. (7). In some samples, internal standard norleucine was included in the hydrolysis and calculation was done on the basis of the recovery of norleucine. To avoid interference due to the large amount of carbohydrates present in the plant materials, all hydrolysates were chromatographed on a Dowex 2-X8, 200-400 mesh column in order to remove humin (8). The column was run with 25 mM sodium citrate buffer, pH 2.2. The column effluent containing the amino acids was lyophilized, redissolved in enough distilled water to a volume which gave the final citrate concentration of 0.2M, and chromatographed in an LKB 4400 automatic amino acid analyser. The resulting chromatograms were quantitated by comparison with that obtained from a standard amino acid calibration mixture.

Trytophan, which was destroyed during acid hydrolysis, was determined by 5 M NaOH hydrolysis, also in a sealed, vacuum tube method according to the Method W of Spies (9).

Sulfur-containing amino acids were not determined separately. They were estimated from the acid hydrolysis chromatograms by assuming that the average loss of methionine in unoxidized samples was 52.3% and that of cysteine + cystine was 62.2%, according to the data obtained by Kaldly and Markakis (3).

RESULTS AND DISCUSSION

The total protein content on a dry weight basis as an average of two determinations showed a range of 11.6% (sayote) to 47.7% (kangkong) with a mean value of 24.9% (Table 1). Although on a wet weight basis the total percentage of protein is normally quite small, the process of lyophilisation obviously concentrated the protein. This was borne out in the potato tuber, whose apparent protein concentration was increased six-fold in one study, from 1.9% to 11.2% (12) or about five-fold from 2.1% to 10.3% in another study (3).

In all the foodstuffs tested, the amounts of glutamic acid and aspartic acid dominated all other amino acids. With the exception of alugbati, cabbage, iba, squash and sayote, aspartic acid constituted more than 10% of the total amino acids of each sample. Glutamic acid constituted more than 10% in all samples other than kangkong, katuray, saluyot and sampaloc.

On the contrary, sulfur-containing amino acids were present at much lower levels. The essential amino acid methionine was especially poor in almost all samples tested. In fact, the amount of methionine in cabbage, camote tops, eggplant, malunggay fruit, pechay and sampaloc fruit was extremely small, less than one percent of total amino acid in each case. Methionine has also been found to be limiting in many plant foodstuffs such as legumes (13), leaf protein concentrates (14) and potato (3).

The next essential amino acid that seemed to be present in low amount was phenylalanine. The deficiencies of methionine and phenylalanine were not apparent in terms of percentage of total amino acids as shown in Table 1. However, when the daily amounts of proteins needed to maintain nitrogen balance are computed as shown in Table 2, it was obvious that methionine as well as phenylalanine supplementation would be needed, in general, to give a balanced protein diet. Exceptions were found in cadyos and mongo where tryptophan was limiting, in sampaloc fruit and singkamas where isoleucine was limiting and in bamboo shoots where lysine was limiting. This was in addition to methionine deficiencies in the said materials.

Although the computations given in Table 2 indicated obvious deficiencies in the foodstuffs tested, their biological values could be compared in a different manner. The quality of the proteins and therefore the first approximation of their biological values was scored as a "percentage of adequacy" against a reference "ideal protein" recommended by FAO/WHO and is given in Table 3. Tyrosine and cysteine + cystine were included because of their sparing action on phenylalanine and methionine, respectively. The protein score, based on the limiting amino acids, was very widely spread between 17 for upo, and 100 for alugbati and sayote. The deficient amounts of methionine could not be compensated for by cysteine + cystine and therefore limited the biological value of most samples tested. On the other hand, tyrosine did indeed correct some limitations due to phenylalanine. In addition some inadequacies in lysine, or leucine could be demonstrated using calculations of this kind. For comparison, we cite other protein scores from the same FAO/WHO Report: whole egg, 100; human milk, 100; cow's milk 95; soya bean 74, sesame 50, groundnut 65, cottonseed 81, maize 49, millet 63, polished rice 67 and whole wheat, 53. Therefore, it could be seen that many of the fruits and vegetables listed in Table 3 compared favorably in terms of their protein scores.

It might be concluded on the basis of the amino acid compositions obtained that most of the samples tested had proteins of high nutritional

Table 1. Amino acid composition of freeze-dried fruits and vegetables.

Protein Source		% Protein	Amino Acids [a]																	
			Essential [b]								Non Essential									
Common Name	Botanical Name		Lys	Phe	Met [c]	Thr	Leu	Ile	Val	Try	Arg	His	Tyr	Cys [c]	Asp	Ser	Glu	Pro	Gly	Ala
Alugbati	*Basella alba*	30.2	5.8	4.5	0.8	5.0	7.7	4.4	6.4	1.6	5.5	2.1	2.0	3.0	9.0	5.4	13.3	5.6	9.4	8.3
Ampalaya Leaves	*Momordica charantia*	30.7	5.4	4.2	2.6	4.6	7.3	4.2	5.8	3.1	4.6	2.1	2.5	1.2	13.5	5.9	11.8	5.0	8.5	7.7
Baguio Beans (Kentucky Beans)	*Phaseolus vulgaris* Linn.	19.9	5.2	3.3	1.5	4.7	6.6	4.0	5.4	1.4	3.8	2.0	1.9	0.63	19.2	7.1	12.7	6.0	6.9	7.7
Bamboo Shoots	*Bambusa blumeana*	26.5	2.0	3.3	3.4	5.0	7.6	3.5	5.3	2.8	3.4	1.5	2.7	1.3	11.3	7.3	12.6	5.9	10.4	10.5
Cabbage	*Brassica oleracea var. capitata*	28.7	2.7	1.5	0.4	2.4	2.7	1.6	2.1	1.0	3.2	1.8	1.0	0.4	7.0	3.6	12.9	48.7	3.4	3.6
Cadyos (Pigeon Pea)	*Cajanus cajan*	27.8	6.0	5.9	1.9	3.9	7.5	3.7	4.4	0.5	4.2	3.3	1.8	0.83	11.1	5.4	19.2	5.8	6.1	8.5
Camote Tops (Sweet Potato Leaves)	*Ipomoea batatas* Lam.	26.0	4.9	4.2	0.6	10.4	7.3	4.0	5.4	3.7	4.1	1.8	1.9	2.0	12.7	5.5	10.4	5.2	8.2	7.5
Cucumber		37.4	6.5	2.8	1.9	3.5	5.6	3.5	4.4	1.0	4.4	1.8	1.8	1.9	11.9	6.3	20.8	3.0	9.1	10.0
Eggplant	*Solanum melongina*	18.7	5.6	3.3	0.7	4.6	5.5	3.2	4.4	3.5	5.5	2.5	2.2	0.7	15.1	5.8	20.1	4.1	6.8	6.2
Gabi Leaves (Taro)	*Colocasia esculenta*	23.5	5.4	4.1	2.4	4.5	6.7	4.0	6.3	2.5	5.0	2.1	2.6	1.5	12.5	5.0	13.5	4.7	8.5	8.6
Gabi Rhizomes (Takway)	*Colocasia esculenta*	22.0	5.0	3.0	2.1	4.3	6.3	3.7	5.3	2.1	4.4	1.8	1.9	1.1	20.2	6.7	11.3	4.5	7.4	8.9

Iba (Camyas)	*Averrhoa bilimbi* Linn.	17.9	3.6	3.3	1.4	4.7	5.7	3.0	4.2	9.0	8.6	2.0	2.1	3.0	9.7	6.7	22.6	7.5	7.0	6.7
Kalabasa Leaves (Squash)	*Cucurbita maxima*	27.6	5.1	4.3	3.5	3.2	6.6	4.7	6.4	2.9	4.9	2.1	2.2	1.5	15.5	3.7	10.7	3.7	9.1	9.7
Kalabasa Fruit (Squash)	Cucurbita maxima	20.5	3.9	3.0	1.8	3.1	5.2	2.9	4.9	0.7	3.4	1.6	1.4	2.1	9.4	5.2	10.2	5.0	29.2	7.0
Kangkong	*Ipomoea aquatica*	47.7	5.3	4.1	1.5	4.6	6.8	3.8	5.2	2.0	4.8	2.2	2.2	0.4	21.1	5.2	9.8	4.6	8.1	8.2
Kulitis	*Amanthus spinosus*	34.8	4.8	4.3	3.5	5.0	8.3	4.7	5.7	2.9	4.1	1.7	2.7	1.3	10.5	5.9	10.7	5.1	9.6	9.5
Katuray	*Sesbania grandiflora* Linn.	33.2	4.3	3.1	2.2	4.0	5.2	3.2	4.4	1.3	3.4	1.6	1.9	1.0	30.5	6.3	8.4	4.2	6.3	8.8
Malunggay Leaves	*Moringa oleifera*	23.8	4.2	5.2	1.3	4.9	7.0	4.0	6.5	1.5	4.9	2.2	1.8'	1.5	11.6	7.0	18.2	3.8	7.0	7.2
Malunggay Fruit	*Moringa oleifera*	29.0	3.9	2.3	0.6	3.8	4.2	2.3	3.0	4.3	3.1	1.6	1.5	0.23	10.2	6.0	23.6	6.8	16.8	5.6
Mongo	*Phaseolus radiatus* Linn.	24.0	6.2	4.8	2.0	3.7	7.4	4.6	5.4	1.0	5.3	2.6	2.2	0.4	10.6	6.0	15.4	10.4	6.2	5.8
Okra	*Abelmoschus esculantus* Linn.	23.8	4.3	2.7	1.9	3.9	4.9	3.0	3.9	4.4	3.8	2.0	1.7	0.8	21.1	5.4	19.7	3.7	6.1	6.6
Patani	*Phaseolus lunatus* Linn.	22.0	6.7	4.8	0.9	5.0	6.9	4.1	4.7	1.4	4.6	2.7	2.6	1.5	12.3	7.3	13.0	8.2	7.5	6.5
Patola	*Luffa acutangula* Linn.	17.8	6.4	3.0	2.6	4.8	7.9	3.4	6.2	1.7	3.2	2.4	2.6	0.7	12.6	6.9	14.1	4.6	9.1	8.9

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Table 1 continued

Pechay	*Brassica chineisis* Linn.	26.6	6.0	4.7	0.4	5.1	6.8	3.6	5.5	2.4	5.0	2.2	0.5	0.4	13.1	6.0	15.9	5.4	9.3	7.7
Puso (Banana Blossom)	*Musa paradiciaca*	21.1	4.7	3.0	2.3	4.1	6.0	4.0	5.2	4.8	5.0	2.0	1.9	0.73	12.6	5.5	16.1	6.6	7.7	7.8
Saluyot	*Oochorus oletorius* Linn.	27.8	4.9	4.4	2.5	4.2	7.1	4.1	6.1	3.1	4.9	2.1	2.4	2.7	15.4	4.7	9.9	4.6	8.2	8.6
Sampaloc Fruit (Tamarino)	*Tamarindus indica* Linn	15.8	6.0	5.0	0.7	5.0	5.3	2.7	3.9	5.0	3.7	2.3	2.8	1.3	16.2	7.9	9.7	6.7	8.7	7.3
Sayote (Chayote)	*Sechium edule* (Jacq.) Swartz	11.6	7.4	4.2	1.5	5.4	8.1	4.7	5.7	2.6	4.1	2.5	3.5	2.1	10.4	6.3	10.8	5.8	8.3	6.6
Singkamas	*Brassica rapa*	19.0	5.3	5.1	1.3	3.9	5.2	3.0	4.7	1.6	3.1	2.4	2.2	10.9	19.7	4.0	11.0	4.2	6.1	6.3
Sitao (String Beans)	*Vigna sesquipedacis*	24.5	5.5	3.8	1.9	4.3	6.5	3.9	5.5	1.0	3.8	3.1	1.9	0.9	14.4	6.7	15.3	6.7	6.9	8.5
Tanglad	*Andropogon citratutus* DC	19.6	5.3	3.0	1.9	4.5	6.6	3.9	5.8	2.1	5.0	2.0	2.0	1.0	19.0	7.0	13.5	12.5	8.1	9.0
Ubi (Yam)	*Dioscorea alata* Linn.	19.8	4.3	3.8	8.8	3.2	6.1	3.3	4.3	1.6	3.9	1.6	2.7	10.1	11.7	6.7	10.6	4.7	6.6	6.0
Upo (Bottlegourd)	*Legenaria siceraria*	22.3	4.4	4.6	0.6	5.3	6.9	4.3	5.0	4.0	4.0	2.5	2.6	0	14.1	7.3	14.2	5.0	8.4	6.7

[a] Amino acids expressed as per cent calculated from total amino acids recovered. When calculations were based on crude protein (N x 6.25), differences were within experimental error. Since amino acid content and not total nitrogen limits nutritive value of crude proteins, and little nonprotein nitrogen was present, protein content was expressed as total amino acid residues.

[b] Required by adult man (10, 15).

[c] Total methionine content and cysteine + cystine content were adjusted respectively, by assuming that 52.3% and 62.2% of these amino acids had been lost during acid hydrolysis according to Kaldy and Menkakis (3).

Table 2. Amount of protein in food stuffs providing recommended level of each essential amino acid to maintain nitrogen balance in adult man.

	Amino Acids[a]								
	Lys	Phe	Met	Thr	Leu	Ile	Val	Try	Minimum
	Recommended Grams Per Day								Amount
	1.6	2.2	2.2	1.0	2.2	1.4	1.6	0.5	needed[b]
Alugbati	28	49	275	20	29	32	25	31	49
Ampalaya leaves	30	52	84	22	30	33	28	16	52
Baguio Beans	31	67	146	21	33	35	30	36	67
Bamboo Shoots	80	67	65	20	29	40	30	18	80
Cabbage	60	147	550	41	83	88	75	51	147
Cadyos	27	37	116	26	29	38	36	100	100
Camote Tops	32	52	367	10	30	35	30	13	52
Cucumber	24	79	116	29	39	40	36	50	79
Eggplant	29	63	314	22	40	43	37	14	63
Gabi Leaves	30	54	92	22	33	35	25	20	54
Gabi Rhizomes	32	73	104	23	35	38	30	24	73
Iba	44	66	157	21	39	47	38	6	66
Kalabasa Leaves	32	51	62	31	33	30	25	17	51
Kalabasa Fruit	41	73	122	32	42	48	33	71	73
Kangkong	30	54	146	22	32	37	31	25	54
Kulitis	33	52	63	20	27	30	28	18	52
Katuray	38	71	100	25	43	44	36	38	71
Malunggay Leaves	38	42	164	21	31	35	24	33	42
Malunggay Fruit	41	94	454	27	52	60	53	12	94
Mongo	26	45	108	27	30	30	30	50	50
Okra	37	81	115	25	45	47	41	11	81
Patani	24	46	245	20	32	34	34	36	46
Patola	25	73	85	21	28	41	26	29	73
Pechay	27	47	550	20	32	39	29	21	47
Puso	34	73	96	24	37	35	31	10	73
Saluyot	22	53	144	19	27	30	28	20	53
Sampaloc Fruit	27	44	318	20	42	53	41	10	53
Sayote	22	54	79	18	24	25	25	19	54
Singkamas	30	43	168	26	42	47	34	31	47
Sitao	29	58	116	23	34	36	29	50	58
Tanglad	30	72	118	22	33	36	28	23	72
Ubi	38	58	25	31	36	43	37	31	58
Upo	36	48	371	19	32	32	32	12	125

[a]Grams of protein needed to provide amino acid to maintain nitrogen balance in adult man. Dietary levels according to Rose (10).

[b]Total grams protein needed to provide sufficient essential amino acids (except methionine) to maintain nitrogen balance in adult man. Methionine supplementation assumed.

Table 3. Protein scores of freeze-dried fruits and vegetables based on reference amino acid pattern[a].

Foodstuffs	Lys	Phe + Tyr	Met + Cys	Thr	Leu	Ile	Val	Try	Protein Score[b]
Alugbati	>100	>100	>100	>100	>100	>100	>100	>100	>100
Ampalaya Leaves	98	>100	>100	>100	>100	>100	>100	>100	98
Baguio Beans	94	87	61	>100	94	>100	>100	>100	61
Bamboo Shoots	36	>100	>100	>100	>100	88	>100	>100	36
Cabbage	49	42	23	60	45	40	42	>100	23
Cadyos	>100	>100	78	98	>100	93	88	50	50
Camote Tops	89	>100	74	>100	>100	>100	>100	>100	74
Cucumber	>100	77	>100	88	>100	88	88	>100	77
Eggplant	>100	92	40	>100	79	80	88	>100	40
Gabi Leaves	98	>100	>100	>100	96	>100	>100	>100	96
Gabi Rhizomes	91	82	91	>100	90	93	>100	>100	82
Iba	65	90	>100	>100	81	75	84	>100	65
Kalabasa Leaves	93	72	>100	80	94	>100	>100	>100	72
Kalabasa Fruit	78	73	>100	78	74	73	98	70	70
Mongo	>100	>100	69	93	>100	>100	>100	>100	69
Kangkong	96	>100	54	>100	97	95	>100	>100	54
Kulitis	87	>100	>100	>100	>100	>100	>100	>100	87
Katuray	78	83	91	>100	74	80	88	>100	74
Malunggay Leaves	76	>100	80	>100	>100	>100	>100	>100	76
Malunggay Fruit	71	63	24	95	60	58	60	>100	24
Mongo	>100	>100	69	93	>100	>100	>100	>100	69
Okra	78	73	77	98	70	75	78	>100	70
Patani	>100	>100	69	>100	99	>100	94	>100	69
Patola	>100	93	94	>100	>100	85	>100	>100	85
Pechay	>100	87	23	>100	97	90	>100	>100	23
Puso	85	82	86	>100	86	>100	>100	>100	82
Saluyot	89	>100	>100	>100	>100	>100	>100	>100	89
Sampaloc Fruit	>100	>100	57	>100	76	68	78	>100	57
Sayote	>100	>100	>100	>100	>100	>100	>100	>100	>100
Singkamas	96	100	100	98	74	75	94	100	74
Sitao	>100	95	80	>100	93	98	>100	>100	80
Tanglad	96	83	83	>100	94	98	>100	>100	83
Ubi	78	>100	>100	80	87	83	86	>100	78
Upo	80	>100	17	>100	99	>100	>100	>100	17

[a]Provisional amino acid scoring pattern according to FAO/WHO, 1973 (11).

[b]Protein score is based on the lowest score obtained for any of the essential amino acid (i.e. the "most limiting amino acid") according to FAO/WHO, 1973 (11).

quality, if methionine and phenylalanine were supplemented to a lesser extent. Although the amino acid composition alone does not infer biological value and that digestibility and feeding experiments have to be carried out to realize this, the present study indicates that these plant foodstuffs may be useful in helping to alleviate demand on much more expensive animal proteins.

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